

# **An Inventory of California Driver Accident Risk Factors**

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The compilation is being published as a technical product of the Research and Development Section rather than a formal report of the State of California. As such, the opinions and findings are those of the authors and may not represent the opinions and beliefs of the State of California.

## EXECUTIVE SUMMARY

### Background and Objective

- Since 1964, the California DMV has issued a number of monographs on driver characteristics and accident risk factors as part of a series known as the California Driver Record Study.
- The present compilation is based on a driver record file data extraction through 1991. The total sample size represents 1% of all licensed drivers, or approximately 200,000 records. The specific sample sizes for the analyses vary depending on the type of analysis and the time intervals involved.
- The objective of the compilation is to provide driver license officials, epidemiologists, traffic safety researchers, and organizations involved in risk assessment and risk management with actuarial data on driver accident risk profiles.

### Findings

- Most drivers have very good records. Extremely deviant records are quite rare; less than 1% of the California driving population are classified as prima facie negligent drivers (four or more points in 12 months, six or more points in 24 months, or eight or more points in 36 months).
- Men have poorer records than do women, largely because they drive more miles.
- For both sexes, driver age is related to accidents and citations. Teen drivers have the highest accident-involvement and citation rates. As drivers age, their accident-involvement rate decreases through about age 69 and then increases somewhat. As drivers age, their citation rate decreases substantially.

- Accident risk increases as a function of the number of accidents and citations on the driver's prior record. Of the two, prior citations is slightly superior as an indicator of subsequent accident risk.
- Subsequent accident risk can be more accurately predicted from a combination of prior accident and prior citation information than from either alone.
- Use of a longer period for counting prior incidents increases the accuracy of accident-risk prediction.
- The inclusion of traffic violator school dismissals in the prior citation counts results in increased accuracy of accident-risk assessment.
- Contrary to intuition, the number of total accidents (irrespective of culpability) is a better indicator of subsequent accident risk than are culpable accidents.
- Negligent-operator (neg-op) points are slightly better predictors of future accident risk than are prior accidents and prior citations. This relationship provides support for the department's neg-op point system, which triggers license control actions based on a driver's point count.
- In contrast to prior non-major citations, prior major citations (e.g. DUI's) and subsequent accidents display a relationship that is no longer monotonic. This implies that repeat major-citation offenders represent lower risks than one-time offenders. However, sanctions such as jail and license suspension likely function as deterrents, thereby reducing the intrinsic risk associated with repeat drunk-driving offenders.
- The relationships between citations and accidents occurring over the same (concurrent) time period are stronger than those for nonconcurrent time periods.
- Accident risk is a complex function of many variables necessitating the use of multivariate prediction models.
- Application of multiple regression analysis confirmed that prior total citation frequency continues to be the most significant predictor of accident involvement, followed by prior accident involvement frequency. Increased accident involvement was shown to be associated with increased prior citation and accident frequencies, possessing a commercial driver license, being young, being male, having a medical condition on record, and having a physician referral for low visual-acuity on record.
- The relationship or risk gradient between prior incidents and subsequent accident risk is steeper for drivers above age 70 than for younger drivers.
- At lower citation levels, male drivers have a higher accident rate than do female drivers. At higher citation levels, the accident rate for female drivers is approximately equal to, or slightly exceeds, that for male drivers.

- At each prior citation level, commercial drivers have a higher accident rate than non-commercial drivers. However, the relationship between increasing prior citation frequency and subsequent accident risk is slightly higher for non-commercial drivers.
- Although there is some non-linearity and non-additivity (interaction) among the accident-risk predictors, they are of little practical importance in increasing accident-risk prediction.
- The present analysis did not evaluate the predictive value of territorial variables, such as ZIP code. Prior California driver record studies have shown that ZIP-code variables are associated with differential accident risk, although the relationships are modest.

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## INTRODUCTION

The California Driver Record Study Database was created in 1962 and resulted in a 9-volume report series published between 1964 and 1967.<sup>1</sup> That report series, known as the 1964 California Driver Record Study, was summarized in a paper published in Accident Analysis and Prevention (Peck, McBride, & Coppin, 1971).

The original database consisted of a 2% systematic random sample of the California Driver License (DL) file representing all drivers with DL numbers ending with 00 or 01. The sampling ratio was subsequently reduced to 1% (terminal digits 01), and the original manual process was completely automated when California automated its DL file in 1965.

The California Driver Record Study has three primary applications:

1. Operational planning
2. Basic descriptive research
3. Multivariate analysis of driver performance indicators

The main thrust of objective 3 has been the identification of accident-risk correlates, the pursuit of which has guided much of the subsequently published reports and updated file extractions (Gebers, 1990; Gebers & Peck, 1987; Kuan, Peck, & Janke, 1990; Kwong, Kuan, & Peck, 1976; Peck & Kuan, 1983).

The emphasis on accident risk emanates from both epidemiologic and risk-management considerations, as described in several prior papers and monographs (Peck, 1993). The California Department of Motor Vehicles has the responsibility of licensing drivers and controlling driver accident risk through a variety of licensure and post-license control programs. A methodology for assessing accident risk and identifying high-risk drivers is an essential component of risk management and the optimization of driver-control functions.

In addition to identifying high-risk target groups for safety reasons, the isolation of accident-risk factors has other applications, most notably establishing casualty insurance premium structures. California Driver Record Study data have been used repeatedly by the insurance industry in establishing risk-based merit rating systems (Kuan, Peck, & Janke, 1990).

The present report is essentially a statistical compilation of accident-risk factors (relativities) identified through a preliminary analysis of the driver record information extracted in May 1992, providing driving record information through December 1991.

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<sup>1</sup>Two earlier reports based on informal sampling and tallies of driver record information were produced in 1954 and 1958 (California Department of Motor Vehicles, 1958).

The release of information in relatively raw tabular form with minimal narrative and interpretation is a departure from previous reports. The objective is to provide report recipients and users with a comprehensive array of up-to-date accident-risk information. More formal and comprehensive analyses will be published at a later date.

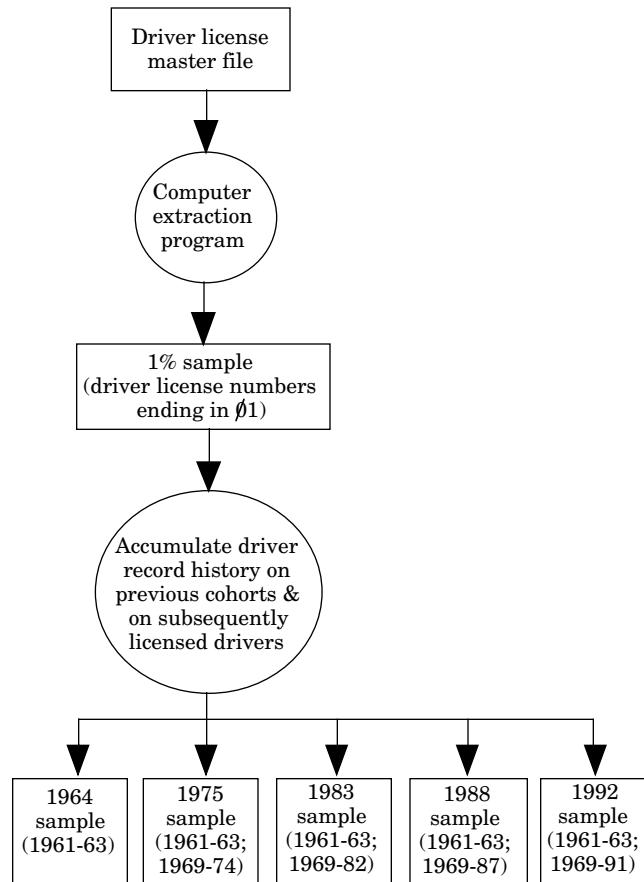
## METHOD

### Sample Design

The California Department of Motor Vehicles (DMV) maintains an automated file containing driving records for over 20 million California drivers. The driver license (DL) number for each record consists of a letter prefix followed by a seven-digit numerical field. License issuance is conducted in such a way that, within each prefix, the lowest numbers are issued first. When all the numbers for a given prefix have been used, a new prefix series is issued. The driver record file is sequenced based on the last two digits of the DL number, from 00 through 99. Within each terminal digit, records are further sorted by letter prefix and the remainder of the DL number. Each terminal digit grouping can, therefore, be conceived of as a 1% random sample of all driver records on file. A 1% random sample of driver records, with DL numbers ending in 01, was extracted from the file on May 1, 1992.

Figure 1 summarizes the data structure of the California Driver Record Study Database, in which the sampled driver records are stored after extraction. As illustrated in the figure, a 1% random sample of the DL file has been extracted five times in the past, beginning in 1964. Driver record history data obtained from each extraction were merged, based on a matching of DL numbers, with data previously extracted for existing cohorts (previous samples). In addition, all drivers in the sample who were licensed after the previous extraction entered the database and formed the basis for future tracking.

Data for the approximately 200,000 driver records extracted in 1992 include almost everything available on the DL file—demographic data, accidents and citations by type, physical and mental (P&M) codes, suspension/revocation actions, and licensing variables such as class of license and driving restrictions. Driver record information stored on the California database covers the period 1961 through 1963 and 1969 through 1991. (Data for 1964 through 1968 were purged from the DL file before they could be extracted and therefore are not in the database.) The time period covered by an individual driver record is a function of when the driver was first licensed in California. In order to be eligible for inclusion into the sample, individuals had to possess a valid California driver license at the time of the extraction. All drivers with a "deceased" indicator on their record or whose driver license has been expired for more than 6 months were deleted from the sample.



Note. The time periods in parentheses represent the years for which driver record histories are available on the database. Due to a purge of data from the department's DL master file, there are no data for 1964-68.

**Figure 1.** Process for creating the California Driver Record Study Database.

Table 1a

Biographical and Licensing Characteristics

Mean age	% male	% class 1/A or 2/B license	% 1 or more restrictions	% physical/mental condition	% under license suspension or revocation	% motorcycle certificate	% residing in Los Angeles County	Median years of licensure in California
41.34	53.9	2.8	32.2	1.3	6.3	4.0	27.4	15

Table 1b

## Percentage of Drivers by Age Group

Age	%
16-29	27.5
30-39	25.2
40-59	31.0
60-69	9.0
70+	7.2

Note. Percentages do not add to 100 due to rounding.

Tables 1a and 1b display biographical and licensing characteristics of the sample.

The tables indicate that:

- 41.3 is the average age, with 27.5% being under age 30 and 7.2% being over age 70.
- 53.9% are males.
- 2.8% hold a class 1/A or 2/B (heavy-vehicle) driver license.
- 4.0% hold a certificate that allows them to operate a motorcycle.
- 32.2% have one or more license restrictions (e.g., must wear corrective lenses while operating a motor vehicle).
- 1.3% have a physical or mental condition on record.
- 6.3% were under a license suspension or revocation action for at least 1 month during the previous year.
- 27.4% of the drivers reside in Los Angeles County.
- 15 years is the median length of licensure in California.

### Design and Analysis

This report presents tabulations of variables related to the assessment of traffic accident risk. (See Appendix for a detailed description of these variables.) The information presented in the following sections range from simple descriptive statistics (e.g., percentages and means) to more complex accident prediction models produced from a statistical technique called multiple regression. Each analysis technique is defined in the relevant section below. It is assumed that the reader is familiar with the issues and terminology associated with traffic accident risk assessment. Therefore, only a minimum amount of narrative is provided. For the interested reader, a more detailed discussion can be found in Kwong, Kuan, and Peck (1976) and Peck and Kuan (1983).



It should be reiterated that it is not the objective of this report to interpret results or make recommendations. Rather, the primary purpose is to provide data on the performance of California's general driving population that may be useful in making policy decisions and formulating public-safety programs, and in evaluating the effectiveness of such policies and programs.

## SECTION 1: DISTRIBUTION OF DRIVER-RECORD ENTRIES BY SEX AND AGE

It has been well established in previous studies that both sex and age are related to accident risk and citation rate (e.g., Gebers & Peck, 1992; Gebers, Romanowicz, & McKenzie, 1993; Peck & Kuan, 1983). In these studies, men had consistently poorer per-driver incident rates than women, and young drivers had poorer per-driver incident rates than older drivers.

To illustrate the relationship between sex and accident risk, Table 2 displays percentage distributions of driver record entries by type and by sex for drivers licensed over 1-, 2-, and 3-year periods during 1989-91. Table 3 presents per-driver average number of entries by type, sex, and driver-record period. It should be noted that the sample sizes for males and females vary because only drivers having a license throughout the requisite time period are included for each interval.

Table 2

Percentage of Driver-Record Entries by Entry Type and Sex  
of Driver for 1-, 2-, and 3-Year Driver Records

Driver-record entry Number of incidents	1991			1990-91			1989-91		
	Both sexes	Male (n = 107,759)	Female (n = 92,567)	Both sexes	Male (n = 103,137)	Female (n = 89,493)	Both sexes	Male (n = 97,769)	Female (n = 86,042)
Total accidents									
0	95.1	94.5	95.8	90.3	89.0	91.8	85.8	83.8	88.0
1	4.7	5.2	4.0	8.8	9.9	7.6	12.4	13.8	10.8
2+	0.2	0.3	0.2	0.9	1.2	0.5	1.8	2.3	1.2
Fatal/injury accidents									
0	98.5	98.3	98.7	96.9	96.4	97.5	95.4	94.6	96.2
1+	1.5	1.7	1.3	3.4	3.6	2.6	4.6	5.4	3.8
Total citations									
0	85.4	81.7	89.8	73.1	67.0	80.2	64.2	56.7	72.8
1	11.8	14.3	8.9	18.3	21.0	15.1	21.2	23.5	18.6
2	2.2	3.1	1.1	5.5	7.2	3.5	8.0	10.2	5.6
3	0.5	0.7	0.2	1.9	2.8	0.9	3.4	4.7	1.9
4+	0.1	0.3	0.1	1.2	1.9	0.3	3.1	4.8	1.0
Total citations excluding traffic violator school citation dismissals									
0	89.4	85.9	93.5	80.4	74.4	87.3	73.2	65.4	82.0
1	8.6	11.1	5.8	13.7	17.0	10.0	16.8	20.1	13.1
2	1.5	2.2	0.6	3.7	5.2	2.0	5.6	7.7	3.3
3	0.3	0.5	0.1	1.3	2.0	0.5	2.3	3.4	1.0
4+	0.1	0.2	0.0	0.8	1.4	0.1	2.0	3.3	0.5

Table 2 (continued)

Driver-record entry Number of incidents	1991			1990-91			1989-91		
	Both sexes	Male (n = 107,759)	Female (n = 92,567)	Both sexes	Male (n = 103,137)	Female (n = 89,493)	Both sexes	Male (n = 97,769)	Female (n = 86,042)
Countable citations									
0	87.5	84.4	91.1	76.7	71.6	82.6	68.6	62.1	76.0
1	10.6	12.8	7.9	17.1	19.8	13.9	20.5	23.2	17.5
2	1.6	2.3	0.8	4.4	5.9	2.8	6.8	8.7	4.6
3+	0.3	0.5	0.1	1.8	2.8	0.7	4.0	5.9	1.8
Moving citations									
0	88.4	85.9	91.4	78.1	73.9	83.0	70.3	64.8	76.5
1	9.9	11.7	7.7	16.3	18.6	13.6	19.8	22.1	17.3
2	1.4	1.9	0.8	4.0	5.2	2.6	6.3	7.9	4.4
3+	0.2	0.4	0.1	1.5	2.3	0.7	1.3	5.1	1.7
Major citations									
0	98.9	98.3	99.7	98.0	96.7	99.4	97.1	95.3	99.1
1	1.0	1.5	0.3	1.8	2.8	0.6	2.5	3.9	0.8
2+	0.1	0.2	0.0	0.2	0.5	0.0	0.4	0.7	0.1
Negligent-operator points									
0	83.8	80.5	87.7	70.8	65.4	77.0	61.3	54.8	68.8
1	12.4	14.2	10.3	19.0	20.9	16.9	22.1	23.4	20.7
2	2.9	4.0	1.7	6.6	8.4	4.5	9.3	11.4	6.9
3	0.6	0.9	0.3	2.2	3.1	1.1	3.9	5.3	2.3
4+	0.2	0.4	0.1	1.3	2.1	0.4	3.2	5.0	1.2
Traffic violator school citation dismissals									
0	94.9	94.4	95.6	88.6	87.3	90.1	83.8	82.0	85.8
1	5.0	5.6	4.4	11.1	12.3	9.7	14.9	16.4	13.3
2+	0.0	0.1	0.0	0.3	0.4	0.2	1.3	1.7	0.9

Note. Samples include only drivers licensed during the entire 1-, 2-, and 3-year periods, respectively. Percentages may not add to 100.0 due to rounding. See the Appendix for definitions of the variables in this table.

Table 3

Mean Number of Driver-Record Entries By Sex of Driver for 1-, 2-, and 3-Year Driver Records

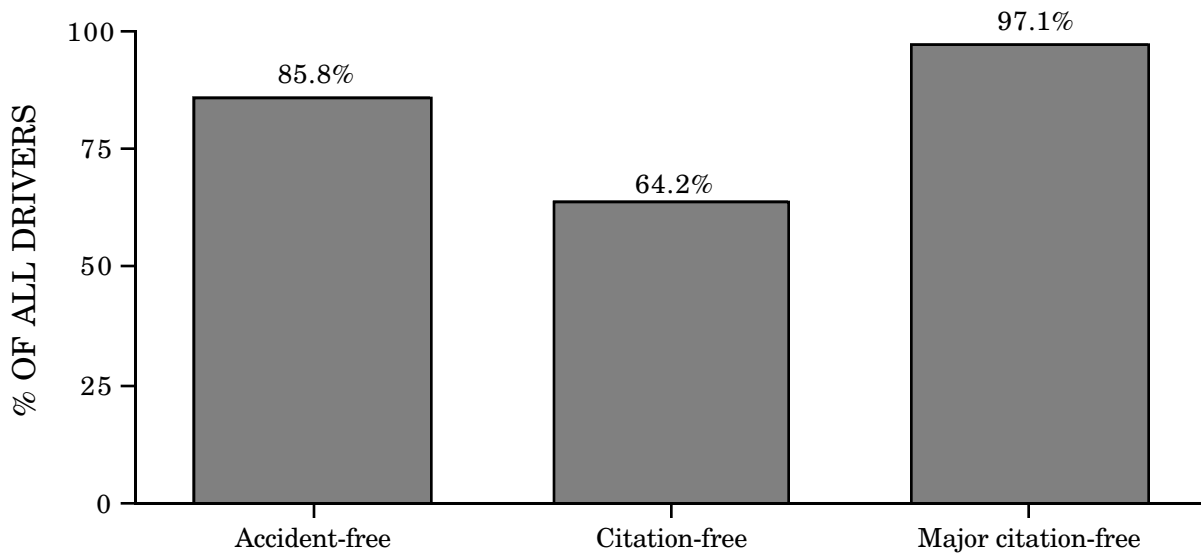
Driver-record entry	1991			1990-91			1989-91		
	Both sexes	Male (n = 107,759)	Female (n = 92,567)	Both sexes	Male (n = 103,137)	Female (n = 89,493)	Both sexes	Male (n = 97,769)	Female (n = 86,042)
Total accidents	0.052	0.059	0.043	0.107	0.124	0.088	0.163	0.189	0.134
Fatal/injury accidents	0.015	0.018	0.013	0.032	0.038	0.026	0.048	0.056	0.039
Total citations	0.183	0.239	0.118	0.408	0.534	0.263	0.632	0.832	0.405
Total citations excluding traffic violator school citation dismissals	0.132	0.181	0.074	0.291	0.403	0.163	0.456	0.634	0.254
Countable citations	0.149	0.191	0.100	0.322	0.412	0.218	0.491	0.631	0.331
Moving citations	0.136	0.170	0.096	0.297	0.370	0.212	0.454	0.571	0.322
Major citations	0.012	0.020	0.003	0.024	0.039	0.006	0.035	0.057	0.009
Negligent-operator points	0.213	0.270	0.146	0.453	0.574	0.312	0.688	0.877	0.474
Traffic violator school citation dismissals	0.051	0.057	0.044	0.117	0.131	0.101	0.176	0.198	0.151

Note. Samples include only drivers licensed during the entire 1-, 2-, and 3-year periods, respectively. See the Appendix for definitions of the variables in the tables.

The data in Tables 2 and 3 indicate that most drivers have very good records, that extremely deviant records are quite rare, and that, as mentioned, men have poorer records than do women.

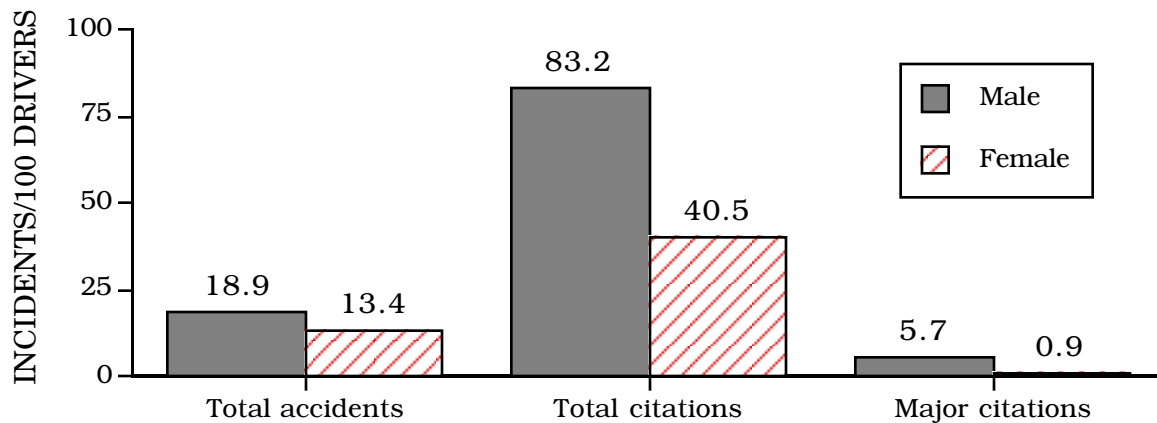
The above relationships are further illustrated in Figures 2 and 3. These figures indicate that during the cumulative 3-year period of 1989-91:

- 85.8% of the drivers were accident-free.
- 64.2% of the drivers were citation-free.
- 97.1% of the drivers did not have a major citation (e.g., driving under the influence of alcohol or drugs and reckless driving) .
- Male drivers had 1.4 times (18.9/13.4) as many total accident involvements, 2.1 times (83.2/40.5) as many total citations, and 6.3 times (5.7/0.9) as many major citations as did women drivers.



*Note.* Based on drivers licensed during the entire 3-year period.

**Figure 2.** Percentage of all drivers who were incident-free during 1989-91.



Note. Based on drivers licensed during the entire 3-year period.

Figure 3. Total accidents, total citations, and major citations per 100 drivers by sex during 1989-91.

For both sexes, driver age is also related to accidents and citations. The annual average accident involvement and citation rates per 100 drivers for each age and sex group are displayed in Table 4.

Table 4

Annual Accident Involvements and Citations Per 100 Licensed Drivers by Age and Sex

Age	Total accident involvements			Total citations		
	Both sexes	Male	Female	Both sexes	Male	Female
16-19	9.36	10.77	7.96	46.75	61.49	29.35
20-24	7.97	8.91	6.79	41.46	53.77	25.92
25-29	6.48	7.37	5.38	31.30	40.32	20.09
30-34	5.58	6.28	4.73	24.27	31.49	15.53
35-39	5.26	5.97	4.44	19.77	25.28	13.47
40-44	4.89	5.51	4.20	17.14	21.50	12.32
45-49	4.68	5.43	3.68	14.95	19.04	10.41
50-54	4.29	5.22	3.24	13.15	17.45	8.35
55-59	4.14	5.01	3.16	11.06	15.10	6.53
60-64	3.76	4.59	2.85	8.39	11.55	4.94
65-69	3.43	4.29	2.55	6.16	8.58	3.69
70-74	3.72	4.61	2.71	5.70	8.07	3.13
75-79	4.00	4.67	3.31	4.16	5.69	2.62
80-84	4.31	5.23	3.34	3.80	5.26	2.27
85+	4.77	5.80	3.51	3.13	4.39	1.16
All ages	5.55	6.41	4.56	21.75	28.57	13.86

Note. Averages represent accidents and citations occurring during 1989-91.

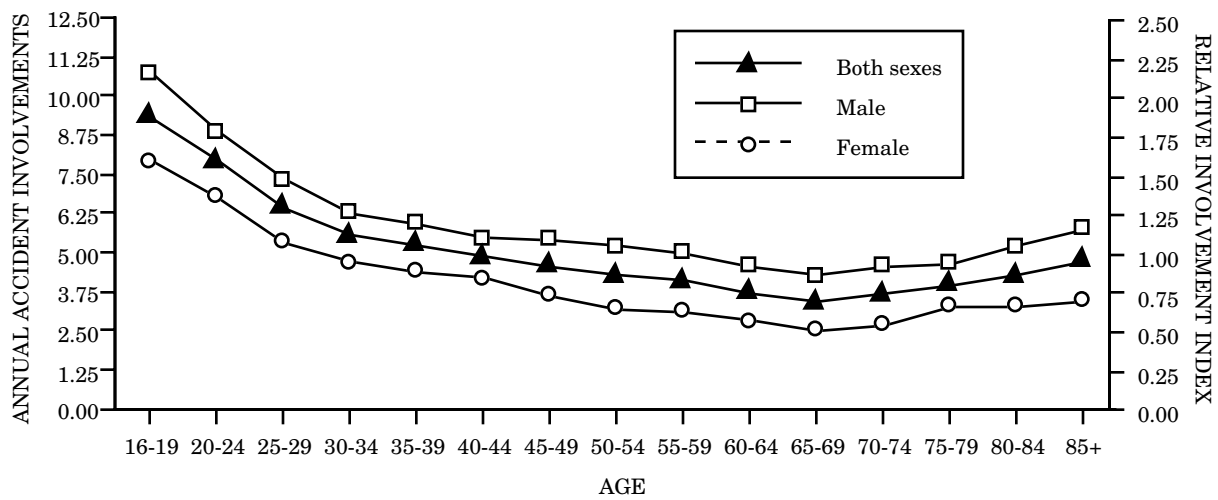
Table 5 shows relative involvement (risk) indices for accident involvements and citations by age and sex. The index for each age/sex group was calculated by dividing the average (mean) accident or citation rate for the group by the grand mean for all drivers. For example, if a certain age/sex group had an accident rate of 10 per 100 drivers, and all licensed drivers had an accident rate of 5 per 100 drivers, the relative involvement index for the group would be 2 (10/5). This would indicate that the age/sex group was involved in twice as many accidents as would be expected relative to all drivers. The indices can be made sex-specific by dividing each age/sex group's index by the "all ages" index for that sex. For example, the accident involvement index for men aged 16-19 as compared to men overall is 1.69 (1.94/1.15).

Because essentially equivalent information is given by group rates and relative indices, Figures 4 and 5 present both types of information, on separate ordinates, for accidents and citations, respectively. In each figure, the left-hand ordinate represents accident involvement or citation rate, and the right-hand ordinate represents relative accident involvement or citation index. These data are from Tables 4 and 5.

Table 5  
Relative Accident Involvements and Citations by Age and Sex

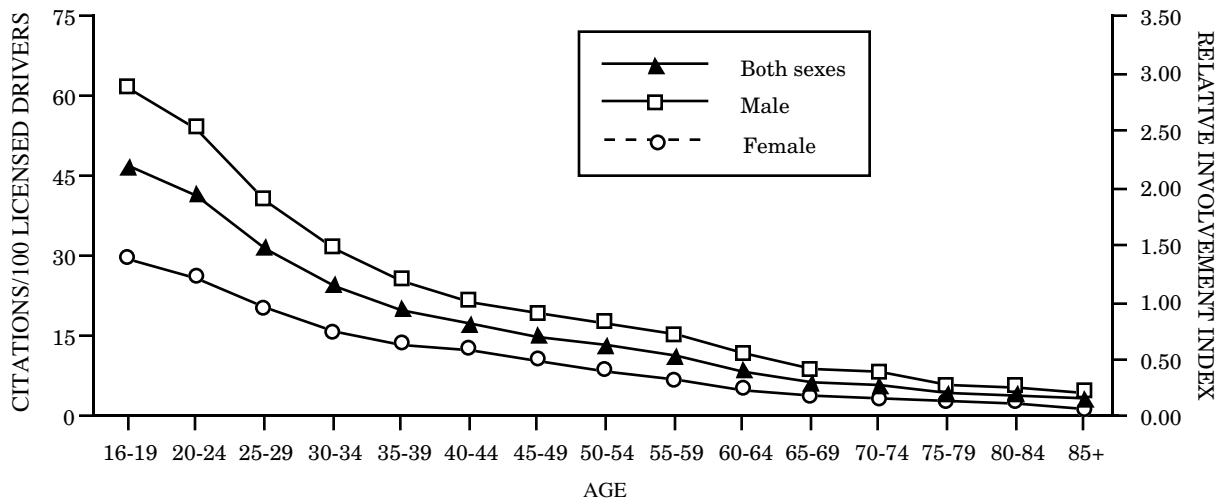
Age	Relative accident-involvement index			Relative citation index		
	Both sexes	Male	Female	Both sexes	Male	Female
16-19	1.69	1.94	1.43	2.15	2.83	1.35
20-24	1.44	1.61	1.22	1.91	2.47	1.19
25-29	1.17	1.33	0.97	1.44	1.85	0.92
30-34	1.01	1.13	0.85	1.12	1.45	0.71
35-39	0.95	1.08	0.80	0.91	1.16	0.62
40-44	0.88	0.99	0.76	0.79	0.99	0.57
45-49	0.84	0.98	0.66	0.69	0.88	0.48
50-54	0.77	0.94	0.58	0.60	0.80	0.38
55-59	0.75	0.90	0.57	0.51	0.69	0.30
60-64	0.68	0.83	0.51	0.39	0.53	0.23
65-69	0.62	0.77	0.46	0.28	0.39	0.17
70-74	0.67	0.83	0.49	0.26	0.37	0.14
75-79	0.72	0.84	0.60	0.19	0.26	0.12
80-84	0.78	0.94	0.60	0.17	0.24	0.10
85+	0.81	1.05	0.63	0.14	0.20	0.05
-----						
All ages	1.00	1.15	0.82	1.00	1.31	0.64

Note. Indices derived from accidents and citations occurring during 1989-91.



Note. Averages represent accidents and citations occurring during 1989-91.

Figure 4. Annual accident-involvement rate and relative involvement index by age and sex.



Note. Averages represent accidents and citations occurring during 1989-91.

Figure 5. Annual citation rate and relative involvement index by age and sex.

Tables 4 and 5 and Figures 4 and 5 indicate that:

- Teen drivers have the highest accident-involvement and citation rates.
- As drivers age, their accident-involvement rate decreases through about age 69 and then rises somewhat.
- As drivers age, their citation rate decreases.

In the above age and sex comparisons on accident risk, mileage is a factor that is not adjusted for. Everything else being equal, higher mileage affords more opportunity for accidents and violations to occur, and males tend to accumulate more mileage than do females. The effect of mileage is covered in Gebers et al. (1993) and therefore is not discussed in detail here.

### Conclusions

- Most drivers have very good records. Extremely deviant records are quite rare.
- For both sexes, driver age is related to accidents and citations.
- Teen drivers have the highest accident-involvement and citation rates. As drivers age, their accident-involvement rate decreases through about age 69 and then increases somewhat. As drivers age, their citation rate decreases.
- Males have a substantially higher incidence of traffic accidents and traffic citations than do females, but much of this gender difference is attributable to the higher driving mileage of male drivers.

## SECTION 2: NONCONCURRENT SUBSEQUENT ACCIDENTS BY PRIOR DRIVER RECORD ENTRIES

### Analytical Procedures

In this section, tabulations of 5-, 6-, 8-, 9-, and 12- year nonconcurrent accidents by driver record incidents are presented. A nonconcurrent relationship is one in which a criterion variable (e.g., subsequent total accidents) can be predicted to some degree by a variable which has been measured during a prior period of time (e.g., prior citations). The analyses of nonconcurrent relationships presented in this section are designed to assist in determining relative risk of future accident involvement on the basis of past driver record performance.

Tables 6 through 40 present a common way of expressing risk in terms of the risk of a no-prior-incident group. To predict accidents in a subsequent period from citations in a prior period (e.g., four citations in the prior 2 years), the average number of subsequent accident involvements for a particular group of drivers is divided by the

average number of subsequent accidents for drivers having no prior citations in the same 2-year period. By using this "times-as-many" relationship, the subsequent accident rate for a group of drivers having a specific number of prior citations is indexed to the accident rate for the zero-prior-citation group. The higher the times-as-many index, the greater the risk of a prior-incident group relative to the risk of the group with no prior incidents, which by definition has a times-as-many index of 1.0. For the example above, a quotient of 4.1 would indicate that the group with four prior citations had 4.1 times-as-many subsequent accidents as had drivers with no prior citations.

Tables 6 through 40 each present a Pearson correlation coefficient. This coefficient is an index of how closely, and in what direction, two variables are related, and can vary from +1 to -1. The Pearson correlation is measured at the individual level in contrast to the times-as-many index, which is measured at the group level. A correlation of +1 or -1 would indicate perfect association, meaning that every individual's score on one variable could be perfectly predicted from their score on the other variable. A correlation of 0 would indicate the complete absence of association. In "real world" prediction, perfect correlations (i.e., -1 or +1) are rarely, if ever, found. The sign of the coefficient indicates the direction of the relationship, with a negative sign indicating an inverse relationship in which one variable tends to increase as the other variable decreases.

Tables 41-52 illustrate three-variable relationships. In each table, the frequency of two prior driver record variables (e.g., citations and accidents) is cross-tabulated with the percentage and mean distributions of subsequent accident involvements. These tabulations allow an assessment of relative accident risk as a function of a combination of two prior driver record variables. (For example, one could assess how the future accident risk of a group of drivers with one prior citation and no prior accidents compares to the future accident risk of a group of drivers with one prior citation and two prior accidents.)

The following results represent driver record trends apparent in these data. The general statements apply to the 5-, 8-, and 9-year data as a whole, whereas specific numerical examples are derived from selected 6- and 12-year distributions.

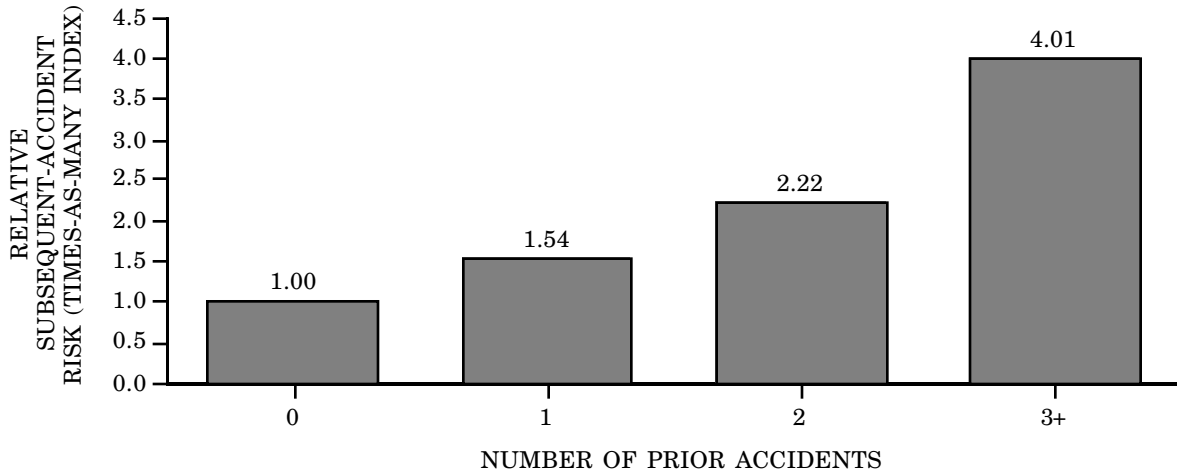
## Results

Two-Variable Relative Risk Relationships. The data presented in Tables 6-40 clearly illustrate the fact that prior driver record is predictive of subsequent accident record. In every case, drivers with prior driver record entries represent a greater risk of subsequent accident involvement relative to drivers with clean records.

Tables 13, 14, and 15: Rate of Subsequent Total Accidents in 1989-91 by the Number of Total Accidents, Citations, and Responsible Accidents in the Prior 3-Year Period (1986-88). This trend is displayed in Tables 13, 14, and 15 and graphically illustrated in Figures 6, 7, and 8. These tables and figures show subsequent accident rate by prior total accidents, prior total citations, and prior total responsible accidents, respectively. Tables 13, 14, and 15 and Figures 6, 7, and 8 indicate that:

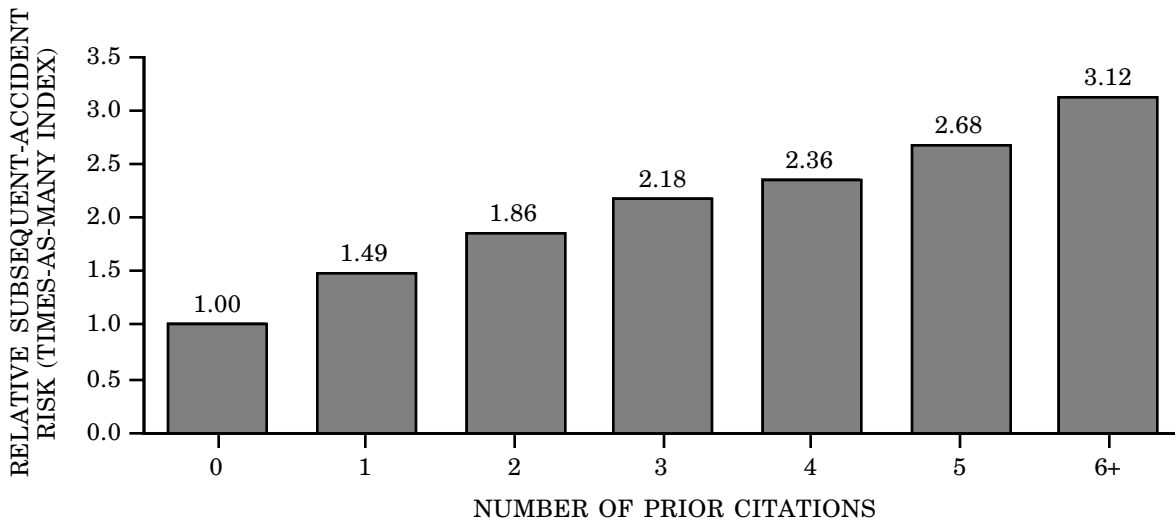


- The group of drivers with three or more accidents in the first 3 years (1986-88) had 4.01 times-as-many accidents in the next 3 years (1989-91) as did the group with no prior accident involvements.



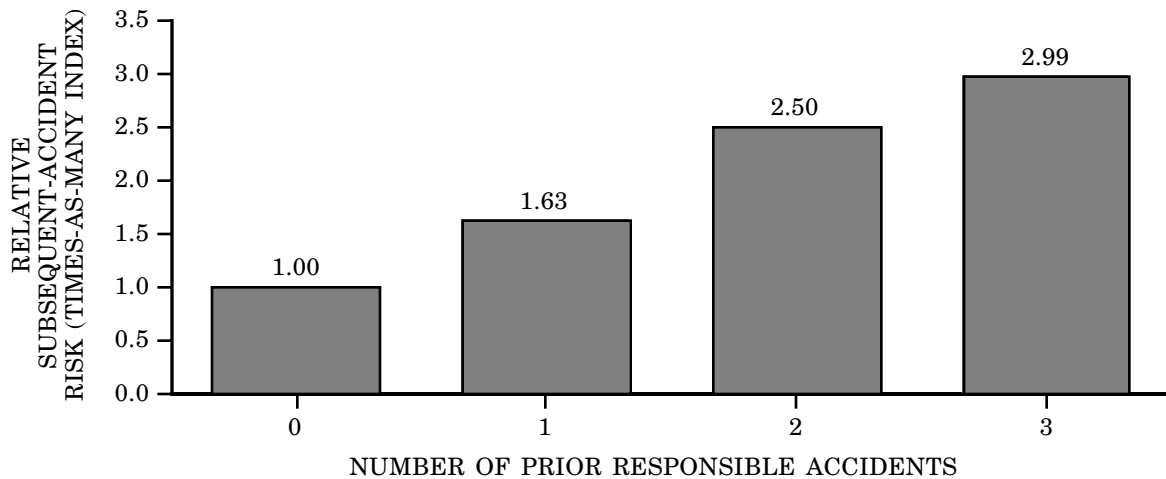
*Note.* Based on subjects licensed during the entire 6-year period.

**Figure 6.** Relative subsequent-accident risk (1989-91) by number of total accidents in the prior 3-year period (1986-88).



*Note.* Based on subjects licensed during the entire 6-year period.

**Figure 7.** Relative subsequent-accident risk (1989-91) by number of citations in the prior 3 years (1986-88).



Note. Based on subjects licensed during the entire 6-year period.

**Figure 8.** Relative subsequent-accident risk (1989-91) by number of responsible accidents in the prior 3 years (1986-88).

- The group of drivers with six or more citations in the first 3 years (1986-88) had 3.12 times-as-many accidents in the next 3 years (1989-91) as did the group with no prior citations.
- The group of drivers with three or more responsible accidents in the first 3 years (1986-88) had 2.99 times-as-many accidents in the next 3 years (1989-91) as did the group with no responsible accidents.

Although large differences in accident-involvement rates exist between driver groups with differing numbers of accidents and citation types, a substantial percentage of drivers, even in the worst groups, remain accident-free. For example, Tables 13, 14, and 15 indicate that:

- 63.04% of the drivers with 3 or more accidents during 1986-88 were accident-free during the next 3 years (1989-91).
- 71.57% of the drivers with 6 or more citations during 1986-88 were accident-free during the next 3 years (1989-91).
- 68.75% of the drivers with 3 or more responsible accidents during 1986-88 were accident free during the next 3 years (1989-91).

As mentioned previously, each table contains a Pearson correlation coefficient measuring the strength of the relationship between prior record and subsequent accident involvement (for different variables and time periods) at an individual, rather than at a group, level. The correlations from Tables 13, 14, and 15 are:

- .091 for the relationship between prior 3-year total accident involvement and subsequent 3-year total accident involvement.
- .120 for the relationship between prior 3-year total citations and subsequent 3-year total accident involvement.
- .051 for the relationship between prior 3-year responsible accidents and subsequent 3-year total accident involvement.

The positive direction of each coefficient indicates that increases in prior accidents and citations are associated with increases in subsequent accident involvements, with prior citations generally functioning as a better predictor of accidents than prior accident involvement. However, the fact that total citations accounts for only 1.4% (.120 x .120) of the variance would indicate that knowing an individual driver had accumulated a certain number of citations during a specific time period would not permit a very accurate estimate of that driver's future accident involvement.

In interpreting these correlations, it is important to keep in mind the distinction between individual and group prediction when evaluating the effectiveness of an accident-prediction system. Peck and Kuan (1983) state that although accurate individual prediction is always a relevant and desirable goal, it is not always a critical or attainable goal. Peck and Kuan note that the actuarial sciences inevitably involve very large numbers of risk entities, and the actuary must establish a premium structure and a funding pool that is sufficient to offset the net dollar amount of claims made over a fixed period of time. For example, if one has established that persons who smoke have a three-fold greater-than-average probability of dying than non-smokers, all members of the smoking group might be charged a higher life insurance premium—presumably one that is proportionate to the greater risk of that group's early mortality. In doing so, it should be recognized that many individuals in the smoking group will not get lung cancer and will actually live longer than average and end up paying more than their "fair share." Conversely, some proportion of non-smokers will contract lung cancer and die early and pay less than their "fair share". A large number of misassessments is a consequence of the fact that smoking still only predicts a small percentage of the variance in the death rate of the individuals comprising any population.

In these Tables, there is a marked trend toward increased accident involvement as a function of a driver's prior accident and citation frequency; however, as noted above, the majority of drivers are accident-free at all prior incident levels. This implies that any graduated premium structure based on prior driver record would necessarily penalize a substantial number of drivers who would not be involved in an accident during the period of time for which the premium is charged. However, when examining the data on a group basis in terms of the number of accidents per 100 drivers in each category, it is evident that drivers with poor records have many more accidents than do drivers who are incident-free. Therefore, from an actuarial standpoint, these data would clearly support charging bad-record drivers higher premiums because the expected number of accident claims filed by these drivers is much higher than that for good-record drivers.

It should also be noted that the results in the tables indicate that the policy of dismissing traffic citations in lieu of attending traffic violator schools (California Vehicle Code Section 42005) distorts DMV's database and reduces the ability to use driver record information to predict, or calibrate, the future accident expectancies of drivers. For example, the correlation of .120 from Table 14 drops to .101 (Table 16) when TVS dismissals are excluded from the citation count. This 16% drop in the magnitude of the correlation corroborates recent DMV studies (Gebers, Tashima, & Marsh, 1987; Peck & Gebers, 1991, 1993). Which have found that, since citation points are valid indicators of future accident risk, any understatement of an offender's citation record results in an underestimate of the offender's accident risk.

Table 19: Rate of Subsequent Accidents in 1989-91 by Number of Negligent-Operator (Neg-Op) Points in the Prior 3-Year Period (1986-88). The relationship between subsequent accidents and prior citations provides solid support for DMV's neg-op point system, which triggers license control actions based on the driver's neg-op point count. The interested reader is referred to Marsh (1992) for the latest evaluation of DMV's Negligent-Operator Treatment System.

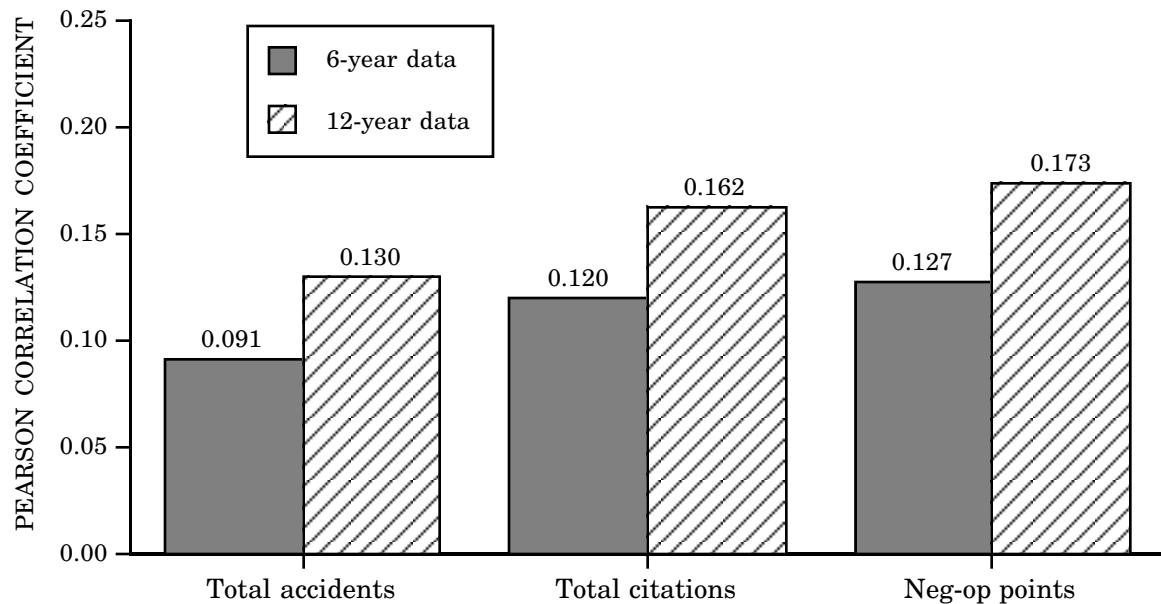
Table 19 presents the accident times-as-many factors based on 6-year data. Because neg-op points are based primarily on convictions of moving violations (comprising the majority of traffic citations), the relationship between accidents and points displayed in the tables is similar to that between accidents and total citations.

The times-as-many indices in Table 19 indicate that:

- The group of drivers accumulating three points in 3 years (1986-88) had 2.27 times-as-many accidents as did the group of clean drivers.
- The group of neg-ops accumulating six or more points in 3 years (1986-88) had 3.14 times-as-many accidents as did the group of clean drivers.

Inspection of comparable correlation coefficients with those for traffic citations indicates that neg-op points are slightly better predictors of future accident risk. For example, the coefficients for 6-year data are .120 versus .127 when using citations and neg-op points, respectively, as predictors (Tables 14 and 19).

Tables 34, 35, and 40: Rate of Total Accidents in 1986-91 by Number of Total Citations, Total Accidents, and Neg-Op Points in the Prior 6-Year Period. One method of increasing the reliability of prior driving incidents as a measure of driving performance is to lengthen the time over which the events are accumulated. Tables 34, 35, and 40 present the relationship between subsequent 6-year accident frequencies by prior 6-year total accidents, total citations, and neg-op points, respectively. Figure 9 compares the correlations for 6-year data with those for 12-year data. In each case, the correlation coefficient for the larger time period is greater. For example, the correlation for 12-year accidents by neg-op points is .173, and that for the 6-year data is .127. Although this increase in correlation is substantial, it still does not represent a strong relationship for predicting the accident involvement rates for individual drivers.



**Figure 9.** Relationship between subsequent accident involvements and prior driving incidents for 6- and 12-year data.

Three-Variable Relative Risk Relationships. Tables 41 through 52 present 6-, 8-, and 12-year "three-way" relative risk tables. These tables allow an assessment of accident risk across levels of various citation types, as well as within each citation level at various levels of prior accident involvement.

Tables 41 and 42: Rate of Subsequent Total Accidents and Responsible Accidents in 1989-91 by Number of Total Citations and Total Accidents in the Prior 3-Year Period. Table 41 displays subsequent total accident involvements by prior total citations and total accidents. Table 42 displays subsequent responsible (culpable) accident involvements by prior total citations and total accident involvements. These data indicate that:

- Drivers with four or more total citations in the prior 3 years have 2.65 times-as-many ( $0.318/0.120$ ) accidents in the subsequent 3 years as drivers with no prior citations.
- Drivers with four or more total citations in the prior 3 years have 4 times-as-many ( $0.117/0.030$ ) responsible accidents as drivers with no prior citations.

The tables also indicate that, within each citation level, drivers with prior accident entries are at a greater risk of future accident involvement. For example,

- Drivers with four or more prior citations and two or more prior accident involvements have 1.54 times-as-many ( $0.448/0.290$ ) subsequent total accidents in the next 3 years as do drivers with four or more prior citations and no prior accidents.

- Drivers with four or more prior citations and two or more prior accident involvements have 1.66 times-as-many (0.171/0.103) subsequent responsible accidents in the next 3 years as do drivers with four or more prior citations and no prior accidents.

Table 43: Rate of Subsequent Total Accidents in 1989-91 by Number of Major Citations and Total Accidents in the Prior 3-Year Period (1986-88). It should be noted that the tables presenting subsequent accidents by prior major citations and prior accident involvements display a relationship that is no longer monotonic. For example, in Table 43 note the relatively modest accident-risk increase for the group with one prior major citation and the even lower accident risk for the group with two or more prior major citations. At first glance, these data seem to suggest that repeat major-citation offenders represent lower risks than one-time offenders. However, according to Peck (1994), a more compelling hypothesis is that the intrinsic risk posed by major (and primarily DUI) offenders has been attenuated by the contingencies arising from their convictions. In addition to the obvious sanctions (e.g., jail and license suspension), there are more subtle agents of change, such as insurance costs, family intervention, and employment loss. These factors would likely function as deterrents, thereby reducing the intrinsic risk associated with repeat major offenders.

#### Conclusions

- Accident risk increases as a function of the number of accidents and citations on the driver's prior record. Of the two, prior citations is slightly superior as an indicator of subsequent accident risk.
- Subsequent accident risk can be more accurately predicted from a combination of prior accident and citation information than from either alone.
- Use of a longer period for counting prior incidents increases the accuracy of accident-risk prediction.
- The total number of accidents on the driver's prior record is a better indicator of subsequent accident risk than are responsible accidents.
- The inclusion of TVS dismissals in the prior citation counts results in increased accuracy of accident-risk assessment.
- Neg-op points are slightly better predictors of future accident risk than are prior accidents and prior citations. This relationship provides solid support for the department's neg-op point system, which triggers license control actions based on a driver's point count.
- In contrast to non-major citations, prior major citations and subsequent accidents display a relationship that is no longer monotonic. The trend seems to imply that repeat major-citation offenders represent lower risks than one-time offenders. However, sanctions such as jail and license suspension likely function as deterrents, thereby reducing the intrinsic risk associated with repeat major citation (primarily drunk-driving) offenders.

Table 6

Rate of Subsequent Total Accident Involvements in 1990-91 by Number  
of Total Accidents in the Prior 3-Year Period (1987-89)

Prior total accidents (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	137,310	0.091	1.00	91.57
1	20,347	0.141	1.55	87.41
2	2,504	0.208	2.29	82.75
3+	364	0.343	3.77	74.45

Note. Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior and subsequent total accidents = .073 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 7

Rate of Subsequent Total Accident Involvements in 1990-91 by Number of  
Total Citations in the Prior 3-Year Period (1987-89)

Prior total citations (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	103,915	0.079	1.00	92.67
1	33,392	0.120	1.52	89.16
2	12,730	0.146	1.85	86.86
3	5,360	0.179	2.27	84.42
4	2,522	0.193	2.44	82.99
5+	2,606	0.217	2.75	81.66

Note. Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .098 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 8

Rate of Subsequent Total Accident Involvements in 1990-91 by Number of  
Responsible Accidents in the Prior 3-Year Period (1987-89)

Prior responsible accidents (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	153,713	0.097	1.00	91.08
1	6,487	0.160	1.65	86.36
2+	325	0.222	2.29	82.15

**Note.** Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior responsible accidents and subsequent total accidents = .041 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 9

Rate of Subsequent Total Accident Involvements in 1990-91 by Number of Total Citations  
(Excluding TVS Dismissals) in the Prior 3-Year Period (1987-89)

Prior total citations (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	116,260	0.085	1.00	92.15
1	27,580	0.125	1.47	88.71
2	9,310	0.150	1.76	86.77
3	3,732	0.165	1.94	85.02
4	1,805	0.183	2.15	84.21
5+	1,838	0.220	2.59	81.72

**Note.** Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .080 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.



**Table 10**  
**Rate of Subsequent Total Accident Involvements in 1990-91 by Number of**  
**Countable Citations in the Prior 3-Year Period (1987-89)**

Prior countable citations (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	110,782	0.081	1.00	92.45
1	32,335	0.125	1.54	88.71
2	10,741	0.154	1.90	86.22
3	4,018	0.193	2.38	83.03
4	1,528	0.206	2.54	83.05
5+	1,121	0.233	2.88	80.64

Note. Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior countable citations and subsequent total accidents = .095 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

**Table 11**  
**Rate of Subsequent Total Accident Involvements in 1990-91 by Number of**  
**Moving Citations in the Prior 3-Year Period (1987-89)**

Prior moving citations (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	113,114	0.082	1.00	92.42
1	31,341	0.127	1.55	88.53
2	10,045	0.158	1.93	85.88
3	3,681	0.199	2.43	82.64
4	1,355	0.203	2.48	83.39
5+	989	0.248	3.02	79.37

Note. Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior moving citations and subsequent total accidents = .096 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 12

## Rate of Subsequent Total Accident Involvements in 1990-91 by Number of Negligent-Operator (Neg-Op) Points in the Prior 3-Year Period (1987-89)

Prior neg-op points (1987-89)	Number of drivers	Mean subsequent accident rate (1990-91)	Times-as-many subsequent accidents <sup>a</sup> (1990-91)	% subsequent accident-free drivers (1990-91)
0	98,799	0.077	1.00	92.86
1	35,419	0.117	1.52	89.34
2	14,774	0.147	1.91	86.92
3	6,221	0.172	2.23	84.79
4	2,809	0.198	2.57	82.84
5	1,253	0.211	2.74	81.88
6+	1,250	0.246	3.19	80.64

Note. Sample is limited to drivers licensed for the entire 5-year period (1987-91). Pearson correlation coefficient between prior neg-op points and subsequent total accidents = .105 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 13

## Rate of Subsequent Total Accident Involvements in 1989-91 by Number of Total Accidents in the Prior 3-Year Period (1986-88)

Prior total accidents (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	130,178	0.138	1.00	87.67
1	19,848	0.213	1.54	82.05
2	2,537	0.306	2.22	75.60
3+	368	0.554	4.01	63.04

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior and subsequent total accidents = .091 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 14

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Citations in the Prior 3-Year Period (1986-88)

Prior total citations (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	98,822	0.120	1.00	89.18
1	31,752	0.179	1.49	84.34
2	12,057	0.223	1.86	81.21
3	5,188	0.261	2.18	77.93
4	2,438	0.283	2.36	76.83
5	1,207	0.322	2.68	73.74
6+	1,467	0.374	3.12	71.57

**Note.** Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .120 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 15

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Responsible Accidents in the Prior 3-Year Period (1986-88)

Prior total responsible accidents (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	146,342	0.147	1.00	86.97
1	6,247	0.239	1.63	80.57
2	310	0.368	2.50	71.61
3+	32	0.438	2.99	68.75

**Note.** Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior responsible accidents and subsequent total accidents = .051 ( $p < .01$ ).

<sup>a</sup>The time-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 16  
Rate of Subsequent Total Accident Involvements in 1989-91 by Number of Total Citations  
(Excluding TVS Dismissals) in the Prior 3-Year Period (1986-88)

Prior total citations (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	109,099	0.128	1.00	88.54
1	26,988	0.186	1.45	83.83
2	9,341	0.222	1.73	81.22
3	3,783	0.253	1.98	78.46
4	1,728	0.280	2.19	77.49
5	898	0.339	2.65	72.38
6+	1,094	0.355	2.77	72.85

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .101 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 17  
Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Countable Citations in the Prior 3-Year Period (1986-88)

Prior total countable citations (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	104,294	0.123	1.00	88.92
1	31,022	0.185	1.50	83.84
2	10,655	0.234	1.90	80.22
3	3,992	0.286	2.33	76.73
4	1,679	0.301	2.45	75.40
5	740	0.349	2.84	74.46
6+	549	0.377	3.07	69.40

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior countable citations and subsequent total accidents = .115 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 18

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Moving Citations in the Prior 3-Year Period (1986-88)

Prior total moving citations (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	106,483	0.124	1.00	88.90
1	30,149	0.189	1.52	83.54
2	9,984	0.241	1.94	79.66
3	3,673	0.283	2.28	76.83
4	1,533	0.313	2.52	74.49
5	643	0.372	3.00	72.94
6+	466	0.393	3.17	68.67

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior moving citations and subsequent total accidents = .117 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 19

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Negligent-Operator (Neg-Op) Points in the Prior 3-Year Period (1986-88)

Prior neg-op points (1986-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	92,859	0.116	1.00	89.46
1	33,770	0.172	1.48	84.82
2	14,558	0.220	1.90	81.36
3	6,136	0.263	2.27	78.11
4	2,858	0.301	2.59	75.68
5	1,375	0.311	2.68	76.22
6+	1,375	0.364	3.14	71.93

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between prior neg-op points and subsequent total accidents = .127 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 20  
Rate of Subsequent Total Accident Involvements in 1987-91 by Number of  
Total Accidents in the Prior 3-Year Period (1984-86)

Prior total accidents (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	119,463	0.233	1.00	80.48
1	17,496	0.349	1.50	72.82
2	2,193	0.504	2.16	63.57
3+	333	0.748	3.21	51.95

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior accidents and subsequent total accidents = .101 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 21  
Rate of Subsequent Total Accident Involvements in 1987-91 by Number of  
Total Citations in the Prior 3-Year Period (1984-86)

Prior total citations (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	90,094	0.202	1.00	82.85
1	28,385	0.299	1.48	75.48
2	10,959	0.356	1.76	71.76
3	4,936	0.425	2.10	67.44
4	2,301	0.471	2.33	64.45
5	1,181	0.489	2.42	62.66
6	634	0.528	2.61	61.83
7	402	0.552	2.73	59.45
8+	593	0.669	3.31	55.82

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .143 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 22

Rate of Subsequent Total Accident Involvements in 1987-91 by Number of Total  
Responsible Accidents in the Prior 3-Year Period (1984-86)

Prior total responsible accidents (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	133,792	0.246	1.00	79.57
1	5,366	0.395	1.61	70.41
2	302	0.543	2.21	63.58
3+	25	0.560	2.28	60.00

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior responsible accidents and subsequent total accidents = .058 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 23

Rate of Subsequent Total Accident Involvements in 1987-91 by Number of Total Citations  
(Excluding TVS Dismissals) in the Prior 3-Year Period (1984-86)

Prior total citations (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	95,451	0.210	1.00	82.27
1	26,120	0.303	1.44	75.30
2	9,560	0.362	1.72	71.37
3	4,070	0.418	1.99	67.57
4	1,936	0.463	2.20	64.26
5	988	0.485	2.31	63.77
6	524	0.548	2.61	61.26
7	332	0.584	2.78	57.83
8+	504	0.639	3.04	57.74

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .131 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 24

Rate of Subsequent Total Accident Involvements in 1987-91 by Number of Total  
Countable Citations in the Prior 3-Year Period (1984-86)

Prior total countable citations (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	93,967	0.207	1.00	82.52
1	28,119	0.305	1.47	75.06
2	10,142	0.376	1.82	70.48
3	4,027	0.435	2.10	66.97
4	1,738	0.491	2.37	63.35
5	759	0.544	2.63	59.42
6	347	0.562	2.71	56.77
7	215	0.647	3.13	57.67
8+	171	0.772	3.73	50.29

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior countable citations and subsequent total accidents = 0.140 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.



Table 25

Rate of Subsequent Total Accident Involvements in 1987-91 by Number of  
Total Moving Citations in the Prior 3-Year Period (1984-86)

Prior total moving citations (1984-86)	Number of drivers	Mean subsequent accident rate (1984-86)	Times-as-many subsequent accidents <sup>a</sup> (1984-86)	% subsequent accident-free drivers (1984-86)
0	96,160	0.208	1.00	82.40
1	27,349	0.309	1.49	74.77
2	9,493	0.379	1.82	70.30
3	3,629	0.450	2.16	65.97
4	1,552	0.512	2.46	62.05
5	676	0.564	2.71	57.99
6	316	0.589	2.83	55.38
7	165	0.679	3.26	56.36
8+	145	0.841	4.04	48.28

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior moving citations and subsequent total accidents = .140 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 26

## Rate of Subsequent Total Accident Involvements in 1987-91 by Number of Negligent-Operator (Neg-Op) Points in the Prior 3-Year Period (1984-86)

Prior neg-op points (1984-86)	Number of drivers	Mean subsequent accident rate (1987-91)	Times-as-many subsequent accidents <sup>a</sup> (1987-91)	% subsequent accident-free drivers (1987-91)
0	84,153	0.195	1.00	83.27
1	30,418	0.291	1.49	76.21
2	13,207	0.353	1.81	72.09
3	5,804	0.414	2.12	68.25
4	2,855	0.450	2.31	65.22
5	1,422	0.532	2.73	61.67
6	729	0.523	2.68	60.91
7	410	0.627	3.22	56.10
8+	487	0.729	3.74	60.78

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Pearson correlation coefficient between prior neg-op points and subsequent total accidents = .150 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 27

## Rate of Subsequent Total Accident Involvements in 1989-91 by Number of Total Accidents in the Prior 6-Year Period (1983-88)

Prior total accidents (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	100,208	0.125	1.00	88.72
1	26,514	0.183	1.46	84.23
2	5,560	0.260	2.08	78.60
3	1,141	0.369	2.95	71.87
4+	322	0.506	4.05	65.22

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior accidents and subsequent total accidents = .106 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 28

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Citations in the Prior 6-Year Period (1983-88)

Prior total citations (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	66,199	0.105	1.00	90.48
1	30,527	0.146	1.39	86.91
2	15,045	0.182	1.73	84.07
3	8,503	0.212	2.02	81.89
4	4,829	0.228	2.17	80.60
5	2,970	0.238	2.27	80.07
6	1,777	0.256	2.44	78.50
7	1,177	0.276	2.63	77.66
8+	2,718	0.327	3.11	74.17

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .124 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 29

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Responsible Accidents in the Prior 6-Year Period (1983-88)

Prior total responsible accidents (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	123,759	0.138	1.00	87.68
1	9,039	0.219	1.59	81.83
2	839	0.306	2.22	76.40
3+	108	0.343	2.49	75.93

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior responsible accidents and subsequent total accidents = .061 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 30

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of Total Citations  
(Excluding TVS Dismissals) in the Prior 6-Year Period (1983-88)

Prior total citations (1983-88)	Number of drivers	Mean subsequent accidents (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	73,451	0.112	1.00	89.91
1	28,965	0.152	1.36	86.37
2	13,306	0.189	1.69	83.55
3	7,145	0.204	1.82	82.46
4	3,941	0.227	2.03	80.79
5	2,375	0.242	2.16	80.00
6	1,451	0.249	2.22	78.64
7	919	0.275	2.46	77.04
8+	2,192	0.325	2.90	74.68

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .110 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 31

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Countable Citations in the Prior 6-Year Period (1983-88)

Prior total countable citations (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	70,549	0.108	1.00	90.20
1	31,022	0.151	1.40	86.49
2	14,731	0.188	1.74	83.56
3	7,655	0.217	2.01	81.50
4	4,158	0.247	2.29	79.39
5	2,311	0.262	2.43	78.41
6	1,309	0.254	2.36	78.99
7	792	0.283	2.62	76.77
8+	1,213	0.375	3.47	71.18

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior countable citations and subsequent total accidents = .121 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 32

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Total Moving Citations in the Prior 6-Year Period (1983-88)

Prior total moving citations (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	72,987	0.109	1.00	90.14
1	30,765	0.154	1.41	86.31
2	14,147	0.192	1.76	83.27
3	7,135	0.223	2.05	81.08
4	3,763	0.256	2.35	78.50
5	2,054	0.264	2.42	78.09
6	1,145	0.254	2.33	79.39
7	698	0.307	2.82	75.21
8+	1,051	0.392	3.60	70.03

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior moving citations and subsequent total accidents = .123 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 33

Rate of Subsequent Total Accident Involvements in 1989-91 by Number of  
Negligent-Operator (Neg-Op) Points in the Prior 6-Year Period (1983-88)

Prior neg-op points (1983-88)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	58,363	0.099	1.00	90.93
1	31,715	0.138	1.39	87.59
2	17,989	0.175	1.77	84.54
3	9,920	0.198	2.00	82.79
4	5,985	0.238	2.40	79.78
5	3,479	0.239	2.41	79.37
6	2,218	0.288	2.91	77.35
7	1,400	0.268	2.71	77.93
8+	2,678	0.329	3.32	74.23

Note. Sample is limited to drivers licensed for the entire 9-year period (1983-91). Pearson correlation coefficient between prior neg-op points and subsequent total accidents = .133 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 34

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of  
Total Accidents in the Prior 6-Year Period (1980-85)

Prior total accidents (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	88,299	0.252	1.00	78.97
1	21,214	0.375	1.49	71.26
2	4,117	0.507	2.01	63.64
3+	988	0.722	2.87	53.95

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior accidents and subsequent total accidents = .130 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 35

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of  
Total Citations in the Prior 6-Year Period (1980-85)

Prior total citations (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	59,326	0.214	1.00	81.82
1	25,743	0.298	1.39	75.64
2	12,396	0.364	1.70	71.12
3	6,641	0.406	1.90	68.97
4	3,719	0.454	2.12	65.93
5	2,307	0.486	2.27	65.06
6	1,420	0.513	2.40	63.24
7	946	0.578	2.70	58.35
8	627	0.625	2.92	57.26
9	417	0.631	2.95	53.72
10+	1,076	0.700	3.27	55.76

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .162 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 36

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of  
Total Responsible Accidents in the Prior 6-Year Period (1980-85)

Prior total responsible accidents (1980-85)	Number of drivers	Mean subsequent accident rate (1989-91)	Times-as-many subsequent accidents <sup>a</sup> (1989-91)	% subsequent accident-free drivers (1989-91)
0	106,902	0.276	1.00	77.74
1	7,057	0.443	1.61	67.71
2	588	0.570	2.07	61.39
3+	71	0.690	2.50	56.34

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior responsible accidents and subsequent total accidents = .078 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.



Table 37

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of Total Citations  
(Excluding TVS Dismissals) in the Prior 6-Year Period (1980-85)

Prior total citations (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	60,993	0.218	1.00	81.52
1	25,322	0.300	1.38	75.54
2	11,995	0.365	1.67	71.12
3	6,407	0.412	1.89	68.67
4	3,510	0.448	2.06	66.47
5	2,181	0.497	2.28	64.14
6	1,337	0.506	2.32	63.72
7	886	0.573	2.63	58.69
8	583	0.624	2.86	56.95
9	389	0.612	2.81	56.56
10+	1,015	0.700	3.21	55.37

**Note.** Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior total citations and subsequent total accidents = .157 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 38

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of  
Total Countable Citations in the Prior 6-Year Period (1980-85)

Prior total countable citations (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	62,335	0.219	1.00	81.43
1	26,007	0.304	1.39	75.29
2	12,117	0.376	1.72	70.38
3	6,115	0.425	1.94	68.00
4	3,301	0.471	2.15	65.13
5	1,893	0.499	2.28	64.24
6	1,126	0.598	2.73	57.46
7	626	0.582	2.66	58.31
8	412	0.651	2.97	55.10
9	249	0.719	3.28	53.41
10+	437	0.751	3.43	53.55

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior countable citations and subsequent total accidents = .160 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 39

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of  
Total Moving Citations in the Prior 6-Year Period (1980-85)

Prior total moving citations (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	64,487	0.222	1.00	81.26
1	25,918	0.308	1.39	74.99
2	11,563	0.380	1.71	70.08
3	5,601	0.439	1.98	67.24
4	2,987	0.488	2.20	64.38
5	1,663	0.524	2.36	62.66
6	936	0.617	2.78	56.52
7	545	0.622	2.80	57.25
8	343	0.644	2.90	55.39
9	211	0.758	3.41	49.76
10+	364	0.783	3.53	52.47

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior moving citations and subsequent total accidents = .161 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 40

Rate of Subsequent Total Accident Involvements in 1986-91 by Number of Negligent-Operator (Neg-Op) Points in the Prior 6-Year Period (1980-85)

Prior neg-op points (1980-85)	Number of drivers	Mean subsequent accident rate (1986-91)	Times-as-many subsequent accidents <sup>a</sup> (1986-91)	% subsequent accident-free drivers (1986-91)
0	52,436	0.201	1.00	82.70
1	26,903	0.285	1.42	76.39
2	14,525	0.354	1.76	72.10
3	8,056	0.397	1.98	69.53
4	4,765	0.453	2.25	65.94
5	2,729	0.493	2.45	64.90
6	1,774	0.524	2.61	61.50
7	1,110	0.561	2.79	61.71
8	799	0.572	2.85	58.70
9	501	0.615	3.06	57.49
10+	1,020	0.686	3.41	55.20

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Pearson correlation coefficient between prior neg-op points and subsequent total accidents = .173 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's subsequent accident rate compared to the zero group's subsequent accident rate.

Table 41

Rate of Subsequent Total Accidents in 1989-91 by Number of Total Citations  
and Total Accidents in the Prior 3-Year Period (1986-88)

Prior total citations (1986-88)	Prior total accidents (1986-88)	Number of drivers	% subsequent total accident-involved drivers (1989-91)			Mean subsequent total accidents (1989-91)
			0	1	2+	
0	0	88,385	89.68	9.39	0.92	0.113
	1	9,502	85.53	12.45	2.02	0.168
	2+	935	78.61	17.33	4.06	<u>0.257</u>
						$\bar{x} = 0.120$
1	0	25,673	85.19	13.24	1.58	0.166
	1	5,328	81.78	15.22	3.01	0.219
	2+	751	73.77	20.51	5.73	<u>0.336</u>
						$\bar{x} = 0.179$
2	0	9,185	82.67	14.61	2.72	0.203
	1	2,426	77.21	19.08	3.70	0.274
	2+	446	72.87	21.08	6.05	<u>0.357</u>
						$\bar{x} = 0.223$
3	0	3,712	79.12	17.78	3.10	0.245
	1	1,199	75.98	19.85	4.17	0.284
	2+	277	70.40	23.10	6.49	<u>0.383</u>
						$\bar{x} = 0.261$
4+	0	3,223	76.17	19.64	4.19	0.290
	1	1,393	73.01	21.68	5.32	0.337
	2+	496	68.75	21.37	9.87	<u>0.448</u>
						$\bar{x} = 0.318$

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Percentages may not add to 100.0 due to rounding.

Table 42

Rate of Subsequent Responsible Accidents in 1989-91 by Number of Total Citations and Total Accidents in the Prior 3-Year Period (1986-88)

Prior total citations (1986-88)	Prior total accidents (1986-88)	Number of drivers	% subsequent responsible accident-involved drivers (1989-91)			Mean subsequent responsible accidents (1989-91)
			0	1	2+	
0	0	88,385	97.24	2.68	0.07	0.028
	1	9,502	96.26	3.60	0.14	0.039
	2+	935	94.87	5.03	0.11	<u>0.052</u>
						$\bar{x} = 0.030$
1	0	25,673	95.77	4.03	0.19	0.044
	1	5,328	94.82	4.95	0.23	0.054
	2+	751	91.21	7.99	0.80	<u>0.096</u>
						$\bar{x} = 0.047$
2	0	9,185	94.77	4.90	0.32	0.056
	1	2,426	92.79	6.72	0.49	0.078
	2+	446	89.46	9.42	1.12	<u>0.117</u>
						$\bar{x} = 0.063$
3	0	3,712	92.81	6.84	0.35	0.076
	1	1,199	91.66	7.84	0.50	0.088
	2+	277	90.61	8.66	0.72	<u>0.101</u>
						$\bar{x} = 0.080$
4+	0	3,223	90.26	9.15	0.59	0.103
	1	1,393	88.08	10.98	0.93	0.123
	2+	496	84.88	13.31	1.81	<u>0.171</u>
						$\bar{x} = 0.117$

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Percentages may not add to 100.0 due to rounding.

Table 43

Rate of Subsequent Total Accidents in 1989-91 by Number of Major Citations and Total Accidents in the Prior 3-Year Period (1986-88)

Prior major citations (1986-88)	Prior total accidents (1986-88)	Number of drivers	% subsequent total accident-involved drivers (1989-91)			Mean subsequent total accidents (1989-91)
			0	1	2+	
0	0	127,448	87.72	10.98	1.30	0.137
	1	18,741	81.99	15.14	2.87	0.214
	2+	2,638	73.96	19.83	6.22	<u>0.340</u>
						$\bar{x} = 0.151$
1	0	2,402	85.10	12.41	2.50	0.177
	1	935	82.46	14.65	2.88	0.211
	2+	206	73.30	21.84	4.86	<u>0.330</u>
						$\bar{x} = 0.195$
2+	0	328	86.59	11.28	2.13	0.159
	1	172	86.05	13.37	0.58	0.145
	2+	61	78.69	19.67	1.64	<u>0.246</u>
						$\bar{x} = 0.164$

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Percentages may not add to 100.0 due to rounding.

Table 44

Rate of Subsequent Total Accidents in 1989-91 by Number of Total Countable Citations and Total Accidents in the Prior 3-Year Period (1986-88)

Prior total countable citations (1986-88)	Prior total accidents (1986-88)	Number of drivers	% subsequent total accident-involved drivers (1989-91)			Mean subsequent total accidents (1989-91)
			0	1	2+	
0	0	92,859	89.46	9.56	0.97	0.116
	1	10,366	85.20	12.68	2.12	0.173
	2+	1,069	77.92	17.87	4.21	<u>0.265</u>
						$\bar{x} = 0.123$
1	0	24,788	84.82	13.53	1.65	0.171
	1	5,423	80.90	15.91	3.19	0.229
	2+	811	73.61	20.22	6.17	<u>0.344</u>
						$\bar{x} = 0.185$
2	0	7,974	81.57	15.55	2.89	0.216
	1	2,242	76.81	19.80	3.30	0.274
	2+	439	73.12	21.18	5.69	<u>0.353</u>
						$\bar{x} = 0.234$
3	0	2,730	78.17	17.95	3.89	0.263
	1	997	74.82	19.96	5.21	0.312
	2+	265	69.06	21.89	9.06	<u>0.423</u>
						$\bar{x} = 0.286$
4+	0	1,827	75.75	20.09	4.15	0.298
	1	820	72.93	21.59	5.49	0.335
	2+	321	67.29	23.05	9.66	<u>0.467</u>
						$\bar{x} = 0.327$

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Percentages may not add to 100.0 due to rounding.



Table 45

Rate of Subsequent Total Accidents in 1987-91 by Number of Total Citations  
and Total Accidents in the Prior 3-Year Period (1984-86)

Prior total citations (1984-86)	Prior total accidents (1984-86)	Number of drivers	% subsequent total accident-involved drivers (1987-91)			Mean subsequent total accidents (1987-91)
			0	1	2+	
0	0	80,919	83.57	14.17	2.27	0.191
	1	8,392	77.29	18.08	4.63	0.286
	2+	783	68.84	23.37	7.79	<u>0.432</u>
						$\bar{x} = 0.202$
1	0	23,274	76.50	19.44	4.05	0.283
	1	4,488	71.88	22.28	5.84	0.356
	2+	623	63.24	27.61	9.15	<u>0.491</u>
						$\bar{x} = 0.299$
2	0	8,450	72.84	21.79	5.37	0.337
	1	2,117	69.63	23.38	6.99	0.393
	2+	392	59.95	27.30	12.77	<u>0.582</u>
						$\bar{x} = 0.356$
3	0	3,583	69.05	23.47	7.49	0.405
	1	1,071	65.17	26.80	8.03	0.452
	2+	282	55.67	33.69	10.63	<u>0.585</u>
						$\bar{x} = 0.425$
4+	0	3,237	64.44	26.85	8.71	0.464
	1	1,428	60.01	28.78	11.20	0.558
	2+	446	54.26	29.60	16.14	<u>0.711</u>
						$\bar{x} = 0.512$

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Percentages may not add to 100.0 due to rounding.

Table 46

Rate of Subsequent Responsible Accidents in 1987-91 by Number of Total Citations and Total Accidents in the Prior 3-Year Period (1984-86)

Prior total citations (1984-86)	Prior total accidents (1984-86)	Number of drivers	% subsequent responsible accident-involved drivers (1987-91)			Mean subsequent responsible accidents (1987-91)
			0	1	2+	
0	0	80,919	95.69	4.12	0.18	0.045
	1	8,392	93.59	5.87	0.54	0.070
	2+	783	91.57	7.66	0.77	<u>0.093</u>
						$\bar{x} = 0.048$
1	0	23,274	93.27	6.31	0.41	0.072
	1	4,488	91.02	8.24	0.74	0.098
	2+	623	90.05	9.15	0.80	<u>0.108</u>
						$\bar{x} = 0.077$
2	0	8,450	91.07	8.18	0.75	0.098
	1	2,117	89.75	9.26	0.99	0.113
	2+	392	84.69	13.52	1.79	<u>0.171</u>
						$\bar{x} = 0.104$
3	0	3,583	89.28	9.77	0.95	0.119
	1	1,071	86.27	12.51	1.21	0.150
	2+	282	80.50	17.02	2.48	<u>0.223</u>
						$\bar{x} = 0.132$
4+	0	3,237	85.60	12.97	1.42	0.161
	1	1,428	82.49	14.92	2.59	0.206
	2+	446	76.46	18.39	5.15	<u>0.294</u>
						$\bar{x} = 0.185$

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Percentages may not add to 100.0 due to rounding.

Table 47

Rate of Subsequent Total Accidents in 1987-91 by Number of Total Major Citations and Total Accidents in the Prior 3-Year Period (1984-86)

Prior total major citations (1984-86)	Prior total accidents (1984-86)	Number of drivers	% subsequent total accident-involved drivers (1987-91)			Mean subsequent total accidents (1987-91)
			0	1	2+	
0	0	116,642	80.60	16.26	3.13	0.231
	1	16,310	72.94	21.07	5.98	0.348
	2+	2,218	61.81	27.10	11.09	<u>0.545</u>
						$\bar{x} = 0.251$
1	0	2,427	74.66	20.81	4.53	0.303
	1	969	70.38	23.22	6.39	0.376
	2+	227	63.00	28.63	8.37	<u>0.476</u>
						$\bar{x} = 0.333$
2+	0	394	79.95	15.99	4.06	0.244
	1	217	74.65	22.12	3.22	0.295
	2+	81	65.43	28.40	6.17	<u>0.457</u>
						$\bar{x} = 0.285$

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Percentages may not add to 100.0 due to rounding.

Table 48

Rate of Subsequent Total Accidents in 1987-91 by Number of Total Countable Citations and Total Accidents in the Prior 3-Year Period (1984-86)

Prior total countable citations (1984-86)	Prior total accidents (1984-86)	Number of drivers	% subsequent total accident-involved drivers (1987-91)			Mean subsequent total accidents (1987-91)
			0	1	2+	
0	0	84,153	83.27	14.36	2.38	0.195
	1	8,960	76.83	18.37	4.80	0.293
	2+	854	67.68	23.89	8.43	<u>0.451</u>
						$\bar{x} = 0.207$
1	0	22,770	76.13	19.70	4.16	0.288
	1	4,640	71.64	22.24	6.12	0.361
	2+	709	63.05	27.64	9.31	<u>0.497</u>
						$\bar{x} = 0.305$
2	0	7,701	71.76	22.40	5.84	0.355
	1	2,026	68.51	24.43	7.06	0.404
	2+	415	56.39	30.36	13.25	<u>0.619</u>
						$\bar{x} = 0.376$
3	0	2,836	68.69	24.08	7.23	0.407
	1	941	64.08	26.99	8.93	0.481
	2+	250	58.40	30.00	11.60	<u>0.580</u>
						$\bar{x} = 0.435$
4+	0	2,003	62.66	28.16	9.19	0.488
	1	929	58.34	30.46	11.21	0.581
	2+	298	54.36	29.53	16.12	<u>0.722</u>
						$\bar{x} = 0.537$

Note. Sample is limited to drivers licensed for the entire 8-year period (1984-91). Percentages may not add to 100.0 due to rounding.

Table 49

Rate of Subsequent Total Accidents in 1986-91 by Number of Total Citations  
and Total Accidents in the Prior 6-Year Period (1980-85)

Prior total citations (1980-85)	Prior total accidents (1980-85)	Number of drivers	% subsequent total accident-involved drivers (1986-91)			Mean subsequent total accidents (1986-91)
			0	1	2+	
0	0	50,122	83.04	14.67	2.28	0.196
	1	8,013	76.54	19.21	4.24	0.287
	2+	1,191	66.16	24.94	8.91	<u>0.462</u>
						$\bar{x} = 0.214$
1	0	19,384	77.01	19.39	3.59	0.272
	1	5,262	72.52	21.25	6.24	0.354
	2+	1,097	66.36	24.07	9.57	<u>0.476</u>
						$\bar{x} = 0.298$
2	0	8,694	72.53	22.31	5.14	0.337
	1	2,966	69.05	23.50	7.45	0.405
	2+	736	62.77	26.63	10.60	<u>0.512</u>
						$\bar{x} = 0.364$
3	0	4,348	71.18	22.75	6.07	0.364
	1	1,746	65.69	25.60	8.70	0.452
	2+	547	61.79	23.40	14.82	<u>0.587</u>
						$\bar{x} = 0.406$
4	0	2,272	68.30	24.21	7.48	0.410
	1	1,051	64.61	24.93	10.47	0.488
	2+	396	55.81	30.81	13.39	<u>0.616</u>
						$\bar{x} = 0.454$
5	0	1,295	67.57	24.09	8.33	0.438
	1	719	62.87	27.12	8.21	0.524
	2+	293	59.39	29.35	11.26	<u>0.604</u>
						$\bar{x} = 0.486$
6	0	763	65.66	24.38	9.95	0.467
	1	444	63.96	25.68	10.36	0.487
	2+	213	53.05	29.11	17.84	<u>0.737</u>
						$\bar{x} = 0.513$
7	0	487	61.40	29.77	8.83	0.497
	1	302	54.97	29.47	15.56	0.682
	2+	157	55.41	31.85	12.74	<u>0.631</u>
						$\bar{x} = 0.578$
8+	0	934	58.67	27.41	13.91	0.602
	1	711	55.27	28.55	16.17	0.691
	2+	475	50.95	30.53	18.52	<u>0.747</u>
						$\bar{x} = 0.664$

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Percentages may not add to 100.0 due to rounding.

Table 50

Rate of Subsequent Responsible Accidents in 1986-91 by Number of Total Citations and Total Accidents in the Prior 6-Year Period (1980-85)

Prior total citations (1980-85)	Prior total accidents (1980-85)	Number of drivers	% subsequent responsible accident-involved drivers (1986-91)			Mean subsequent responsible accidents (1986-91)
			0	1	2+	
0	0	50,122	95.73	4.09	0.18	0.045
	1	8,013	94.40	5.33	0.27	
	2+	1,191	90.26	8.98	0.76	
						$\bar{x} = 0.048$
1	0	19,384	94.38	5.31	0.31	0.060
	1	5,262	91.70	7.64	0.67	
	2+	1,097	89.15	9.48	1.37	
						$\bar{x} = 0.069$
2	0	8,694	92.05	7.43	0.51	0.085
	1	2,966	90.53	8.63	0.83	
	2+	736	85.33	13.32	1.36	
						$\bar{x} = 0.095$
3	0	4,348	90.89	8.37	0.74	0.099
	1	1,746	87.69	11.17	1.15	
	2+	547	83.73	13.53	2.74	
						$\bar{x} = 0.117$
4	0	2,272	88.86	10.30	0.84	0.121
	1	1,051	87.16	11.89	0.95	
	2+	396	82.32	14.90	2.78	
						$\bar{x} = 0.134$
5	0	1,295	87.95	10.42	1.62	0.138
	1	719	85.40	12.93	1.67	
	2+	293	82.94	14.33	2.73	
						$\bar{x} = 0.156$
6	0	763	89.25	9.70	1.05	0.119
	1	444	85.81	12.61	1.58	
	2+	213	79.81	16.90	3.29	
						$\bar{x} = 0.150$
7	0	487	85.01	13.55	1.44	0.164
	1	302	82.45	14.90	2.65	
	2+	157	75.80	21.66	2.55	
						$\bar{x} = 0.196$
8+	0	934	81.80	15.20	2.99	0.214
	1	711	78.34	18.85	2.81	
	2+	475	74.74	19.58	5.68	
						$\bar{x} = 0.252$

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Percentages may not add to 100.0 due to rounding.

Table 51

Rate of Subsequent Total Accidents in 1986-91 by Number of Total Major Citations and Total Accidents in the Prior 6-Year Period (1980-85)

Prior total major citations (1980-85)	Prior total accidents (1980-85)	Number of drivers	% subsequent total accident-involved drivers (1986-91)			Mean subsequent total accidents (1986-91)
			0	1	2+	
0	0	84,805	79.19	17.39	3.42	0.249
	1	19,245	71.45	21.80	6.76	0.374
	2+	4,287	61.88	26.08	12.03	<u>0.554</u>
						$\bar{x} = 0.283$
1	0	2,718	73.66	21.19	5.15	0.325
	1	1,441	68.91	24.08	7.01	0.402
	2+	506	59.68	28.85	11.47	<u>0.546</u>
						$\bar{x} = 0.373$
2	0	622	72.03	21.86	6.10	0.352
	1	396	69.70	24.49	5.80	0.369
	2+	229	64.19	26.20	9.61	<u>0.485</u>
						$\bar{x} = 0.382$
3+	0	154	74.68	22.73	2.60	0.299
	1	132	75.00	18.94	6.07	0.326
	2+	83	61.45	31.33	7.22	<u>0.482</u>
						$\bar{x} = 0.350$

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Percentages may not add to 100.0 due to rounding.

Table 52

Rate of Subsequent Total Accidents in 1986-91 by Number of Total Countable  
Citations and Total Accidents in the Prior 6-Year Period (1980-85)

Prior total countable citations (1980-85)	Prior total accidents (1980-85)	Number of drivers	% subsequent total accident-involved drivers (1986-91)			Mean subsequent total accidents (1986-91)
			0	1	2+	
0	0	52,436	82.70	14.92	2.37	0.201
	1	8,612	75.98	19.50	4.52	
	2+	1,287	66.20	24.63	9.17	
						$\bar{x} = 0.219$
1	0	19,377	76.63	19.59	3.78	0.279
	1	5,434	72.60	20.98	6.43	
	2+	1,196	65.80	24.67	9.53	
						$\bar{x} = 0.304$
2	0	8,290	72.24	22.42	5.33	0.343
	1	3,023	67.38	24.68	7.93	
	2+	804	62.44	26.37	11.19	
						$\bar{x} = 0.376$
3	0	3,846	70.25	23.30	6.46	0.381
	1	1,694	65.47	25.62	8.91	
	2+	575	60.35	25.04	14.61	
						$\bar{x} = 0.425$
4	0	1,975	67.14	24.96	7.90	0.428
	1	916	64.30	24.56	11.14	
	2+	410	57.32	30.24	12.44	
						$\bar{x} = 0.471$
5	0	1,038	67.92	23.41	8.67	0.434
	1	593	62.06	28.33	9.61	
	2+	262	54.58	30.53	14.88	
						$\bar{x} = 0.499$
6	0	559	60.64	29.70	9.66	0.513
	1	391	56.01	27.62	16.37	
	2+	176	50.57	30.68	18.75	
						$\bar{x} = 0.598$
7	0	296	62.84	27.03	10.13	0.503
	1	193	56.48	30.57	12.95	
	2+	137	51.09	35.77	13.14	
						$\bar{x} = 0.582$
8+	0	482	55.39	27.80	16.79	0.681
	1	358	55.59	29.33	15.09	
	2+	258	49.61	29.07	21.32	
						$\bar{x} = 0.706$

Note. Sample is limited to drivers licensed for the entire 12-year period (1980-91). Percentages may not add to 100.0 due to rounding.



## SECTION 3: CONCURRENT ACCIDENTS BY DRIVER RECORD ENTRIES

### Analytical Procedures

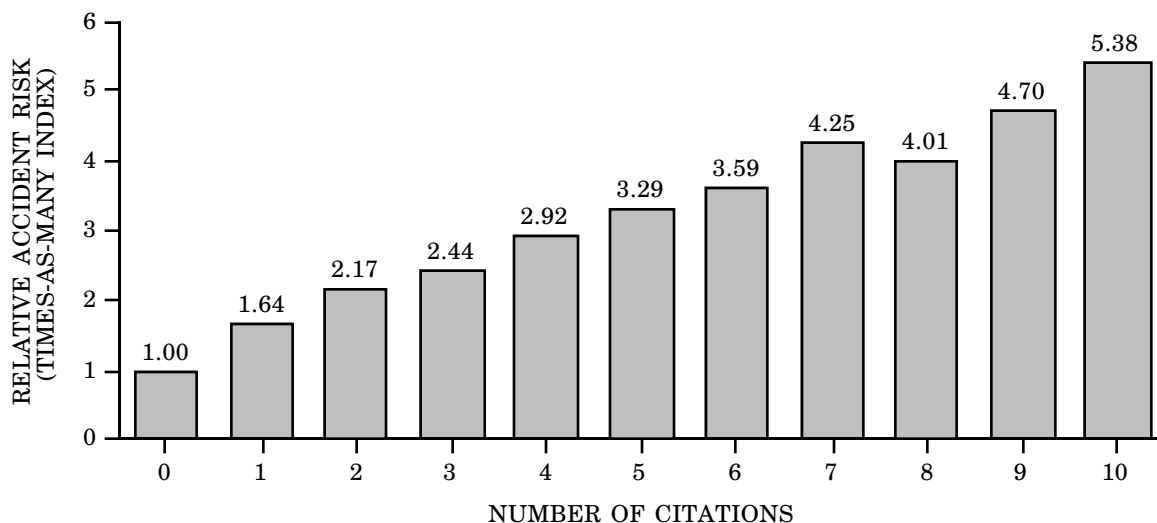
Tables 53 through 56 present the rate of total accidents by number of citations of various types for a concurrent 6-year period. Concurrent data are measured over the same time period.

Concurrent relationships between predictors and criterion measures share some features which limit their use for certain purposes. One serious limitation is that the events may not be independent. For example, the occurrence of an accident can trigger the issuance of a traffic citation, thereby inflating the true association between the two events (Peck, McBride, & Coppin, 1971). Additionally, because the events can occur at any particular time during the interval, the structure of the relationship is not necessarily in a direction compatible with true prediction of the criterion. That is, when predicting accident experience from citation experience, one must be aware that some of the accidents would have occurred prior to some of the violations leading to conviction. The correlations in the tables therefore do not represent truly predictive (nonrecursive) relationships in which the predictor measures are always antecedent to the criterion measures. A third feature to remember is that (everything else being equal) concurrent relationships are inherently stronger than predictive relationships because the variables being correlated are impacted by the same time-dependent exogenous factors. In the case of accidents and citations, for example, both are directly related to the number of miles driven during the same time interval which introduces an additional (non-causal) association between the two types of events.

### Results

As was the case for the nonconcurrent data, the concurrent tables indicate that drivers with successive driver record entries are at a greater risk of accident involvement. For example, Table 53 and Figure 10 show the times-as-many factor for 6-year (1986-91) concurrent total accidents by total citations. These data indicate that:

- Drivers with five citations have over 3 times-as-many accidents during a concurrent 6-year period than do clean-record drivers.



Note. Based on subjects licensed during the entire 6-year period.

**Figure 10.** Relative accident risk by number of total citations during a concurrent 6-year period (1986-91).

- Drivers with 10 or more citations have over 5 times-as-many accidents during a concurrent 6-year period than do drivers with no citations.

As was also the case with the nonconcurrent data, a sizable number of drivers in the worst citation groups remain accident-free. For example, Table 53 indicates that:

- 54% of the drivers with five total citations remain accident-free during a concurrent 6-year period.
- 39% of the drivers with 10 or more total citations remain accident-free during a concurrent 6-year period.

### Conclusions

- As was the case with the nonconcurrent data, the concurrent results indicate that drivers with successive driver record entries are at a greater risk of accident involvement than are drivers with fewer or no driver record entries.
- As was the case with the nonconcurrent data, a sizable number of drivers in the worst citation groups remain accident free.
- The relationships between citations and accidents for concurrent data are stronger than those for nonconcurrent data, as evidenced by the higher correlation coefficients for the former. This finding is to be expected because concurrent data are measured during a common time frame and therefore are influenced by a more similar set of external causal factors than are nonconcurrent data.

Table 53

Rate of Total Accidents by Number of Total Citations  
Accumulated During a Concurrent 6-Year Period (1986-91)

Total citations (1986-91)	Number of drivers	Mean accident rate (1986-91)	Times-as-many accidents <sup>a</sup> (1986-91)	% accident-free drivers (1986-91)
0	75,638	0.200	1.00	82.82
1	35,628	0.328	1.64	73.20
2	17,825	0.433	2.17	66.59
3	9,489	0.487	2.44	63.30
4	5,426	0.583	2.92	57.63
5	3,302	0.658	3.29	53.94
6	1,896	0.717	3.59	51.37
7	1,239	0.849	4.25	45.68
8	829	0.802	4.01	48.01
9	537	0.939	4.70	43.39
10+	1,122	1.075	5.38	39.30

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between total citations and accidents = .253 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's accident rate compared to the zero group's accident rate.

Table 54

Rate of Total Accidents by Number of Total Citations (Excluding TVS Dismissals)  
Accumulated During a Concurrent 6-Year Period (1986-91)

Total citations (1986-91)	Number of drivers	Mean accident rate (1986-91)	Times-as-many accidents <sup>a</sup> (1986-91)	% accident-free drivers (1986-91)
0	90,970	0.230	1.00	80.71
1	31,504	0.359	1.56	71.40
2	13,796	0.454	1.97	65.33
3	6,833	0.533	2.32	60.63
4	3,783	0.605	2.63	56.38
5	2,179	0.697	3.03	52.41
6	1,331	0.754	3.28	49.66
7	816	0.831	3.61	47.67
8	567	0.873	3.80	46.56
9	368	0.924	4.02	42.93
10+	784	1.089	4.73	38.52

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between total citations and accidents = .225 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's accident rate compared to the zero group's accident rate.

Table 55

Rate of Total Accidents by Number of Total Countable Citations  
Accumulated During a Concurrent 6-Year Period (1986-91)

Total countable citations (1986-91)	Number of drivers	Mean accident rate (1986-91)	Times-as-many accidents <sup>a</sup> (1986-91)	% accident-free drivers (1986-91)
0	81,852	0.209	1.00	82.18
1	36,365	0.349	1.67	71.81
2	16,817	0.459	2.20	64.92
3	8,305	0.541	2.59	60.47
4	4,282	0.665	3.18	53.32
5	2,355	0.723	3.46	50.87
6	1,224	0.835	4.00	48.12
7	754	0.862	4.12	46.55
8	433	0.931	4.45	42.49
9	248	1.137	5.44	37.90
10+	296	1.166	5.58	35.81

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between countable citations and accidents = .246 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's accident rate compared to the zero group's accident rate.

Table 56

Rate of Total Accidents by Number of Total Moving Citations Accumulated  
During a Concurrent 6-Year Period (1986-91)

Total moving citations (1986-91)	Number of drivers	Mean accident rate (1986-91)	Times-as-many accidents <sup>a</sup> (1986-91)	% accident-free drivers (1986-91)
0	84,650	0.217	1.00	81.59
1	35,943	0.357	1.65	71.42
2	16,074	0.467	2.15	64.64
3	7,704	0.546	2.52	60.66
4	3,922	0.663	3.06	53.24
5	2,058	0.709	3.27	51.85
6	1,089	0.838	3.86	48.30
7	676	0.846	3.90	47.04
8	365	0.981	4.52	40.55
9	212	1.090	5.02	38.21
10+	238	1.134	5.23	39.50

Note. Sample is limited to drivers licensed for the entire 6-year period (1986-91). Pearson correlation coefficient between moving citations and accidents = .234 ( $p < .01$ ).

<sup>a</sup>The times-as-many factor represents the relative increase in each group's accident rate compared to the zero group's accident rate.

## SECTION 4: ACCIDENT PREDICTION MODELS

### Analytical Procedures

In the previous sections, accident risk relativities were expressed as a function of either one or two driver record variables. Because accident risk is a complex function of many variables, strategies for optimally estimating and predicting individual accident risk must be multidimensional in form. There are several techniques for doing this, but one of the most powerful and frequently used is multiple linear regression. In the case of the accident criterion, the multiple linear regression analysis produces an equation that gives the most accurate possible prediction of individual accident involvement rate, using an optimum linear composite of the mean values of the various independent variables (e.g., sex, age, and prior driving record). The regression equation can also be used to predict along a continuous scale whether or not an individual driver will be involved in a future accident.

Another commonly used statistical modeling technique is multiple logistic regression. In contrast to the continuous criterion scale in linear regression, the criterion scale in logistic regression allows for a criterion value of 0 or 1 (e.g.,  $Y = 1$  if a driver is involved in one or more accidents; otherwise  $Y = 0$ ). The logistic regression model shares a common feature with a more general class of linear models in that a function of the binary response variable is assumed to be linearly related to the explanatory (independent) variables. Use of a logistic regression model allows for the computation of the relative odds, called odds-ratio, of an accident involvement. For example, if males and females were compared on relative accident risk, an odds-ratio greater than 1 would indicate that males are a higher accident risk; a value of 1 would indicate both sexes are of equal accident risk, and a value less than 1 would indicate that males are a lower accident risk.

In this section, results for both linear and logistic regression analyses are presented.

Two linear multiple regression equations or models were computed. The first is a simple additive (or "main effects") model for predicting subsequent accident involvement from prior driver record variables. Stepwise regression analysis was used for identifying which combination of variables from the potential predictor pool provided the most accurate equation for predicting the criterion measure. Only those variables which were statistically significant were included in the final model.<sup>2</sup> The second model examined a subset of variables from the main effects model to determine whether bilinear (two-way) interactions existed among these variables.<sup>3</sup> If an interaction was present, the association between the risk factor (e.g., accident involvements) and the dependent variable would change at different levels of a

<sup>2</sup>A test of statistical significance allows one to determine the probability that an observed difference is due to chance alone. If the probability is sufficiently small, it is concluded that the difference is "real." For the stepwise linear regression analyses, a difference was considered to be statistically significant when the probability of a difference that large or larger (in either direction) occurring by chance was less than 1 in 10 ( $p < .10$ ).

<sup>3</sup>Models evaluating the predictive contribution of non-linear (e.g., quadratic) terms will be presented in more comprehensive analyses to be published at a later date. For example, inclusion of an age-squared term results in accident rates declining until about age 70 and then increasing. The quadratic component, though smaller than the linear component, is statistically significant ( $F = 58.55, p < .01$ ).

covariate (e.g., citations). That is, the covariate moderates the effect of the risk factor.

The results of the multiple logistic regression is presented as a complimentary analysis to the linear main-effects regression model. The focus of this analysis was on the odds-ratio comparisons of a set of two, three, or four risk factors (e.g., drivers with zero citations versus drivers with one or more citations) on accident involvement.

### Results

Table 57 summarizes the 3-year prior and 3-year subsequent additive multiple linear regression equation. This equation contains all variables with a regression coefficient that was significant at the .10 level of probability. The equation resulted in an  $R^2$  of .025, indicating that approximately 2.5% of the variance in total accident involvements is accounted for by the significant predictor variables. Prior total citation frequency was the most significant predictor, followed by prior accident involvement frequency. Six other variables were also statistically significant predictors of accident involvement. The direction (sign) of the regression coefficients indicate that increased accident involvement is associated with:

- Increased prior citation frequency.
- Increased prior accident frequency.
- Having a commercial drivers license (which are mostly held by high-mileage professional drivers).
- Being young.
- Being male.
- Having a medical condition on record.
- Having a physician referral for low visual-acuity on record.

The variables from Table 57 were subjected to a logistic regression analysis. The odds-ratios from the analysis are presented in Table 52. In a manner similar to the times-as-many index presented earlier, the odds-ratio refers to the relative odds of being accident-involved, but as a function of a predicted driver-record category. For example, the odds-ratios in Table 58 indicate that:

- Drivers with one prior citation are 1.15 times as likely to be involved in a subsequent accident as are citation-free drivers.
- Drivers with four prior citations are 1.75 times as likely to be involved in a subsequent accident as are citation-free drivers.
- Drivers with one prior accident are 1.33 times as likely to be involved in a subsequent accident as are accident-free drivers.



- Drivers with three prior accidents are 2.35 times as likely to be involved in a subsequent accident as are accident-free drivers.
- Drivers with a commercial license are 1.68 times as likely to be involved in a subsequent accident than are drivers without a commercial license.

As stated above, the regression models presented in Tables 57 and 58 are additive (main effects) models. Both models fail to account for variation due to a moderated or interactive relationship that may exist between the driver record variables. In order to assess the contribution of any interactions, a subset of variables from Table 57 were added to a model containing all main effects and two-way interactions.<sup>4</sup> The results from this analysis are presented in Table 59.

The results in Table 59 indicate that although the  $R^2$ -change (.001) from adding all two-way interactions is very small, the statistically significant ( $p < .001$ )  $F$ -change value of 19.00 implies that individual accident prediction is enhanced when the two-way interactions are added to the model. In order to illustrate the concept of an interaction, Figures 11, 12, and 13 present the results of three separate two-way interactions in which prior total citations serves as the moderator variable.

Figure 11 displays the expected number of total accidents during a subsequent 3-year period by driver age and prior 3-year total citations. The results indicate that at the lower citation levels, the older drivers are equal to or better than younger drivers in relation to the expected number of subsequent accidents. However, at the higher citation levels, older drivers exhibit higher future accident risk, relative to younger drivers. For example, Figure 11 demonstrates that:

- Among drivers with zero prior citations, there is a rate of 15.24 accidents per 100 drivers for 24 year olds, a rate of 10.97 accidents per 100 drivers for 55 year olds, a rate 8.90 accidents per 100 drivers for 70 year olds, and a rate of 6.83 accidents per 100 drivers for 85 year olds. The difference between 15.26 and 6.83 represents a relative risk differential of 2.23 times-as-many accidents for 24 year old drivers relative to 85 year old drivers.
- Among drivers with four prior citations, there is a rate of 28.05 accidents per 100 drivers for 24 year olds, a rate of 31.74 accidents per 100 drivers for 55 year olds, a rate of 33.52 accidents per 100 drivers for 70 year olds, and a rate of 35.31 accidents per 100 drivers for 85 year olds. The difference between 35.31 and 28.05 represents a relative risk differential of 1.26 times-as-many accidents for 85 year old drivers relative to 24 year old drivers.

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<sup>4</sup>Prior to forming the multiplicative interaction terms, the predictor variable scores were centered. Centering involves subtracting mean scores from the predictor variable scores. Transforming the scores through centering reduces multicollinearity among the variables, thereby reducing the instability in the regression parameter estimates. The interested reader is referred to Cronbach (1987) and Jaccard, Turrisi, & Wan (1990) for a detailed discussion of centering.

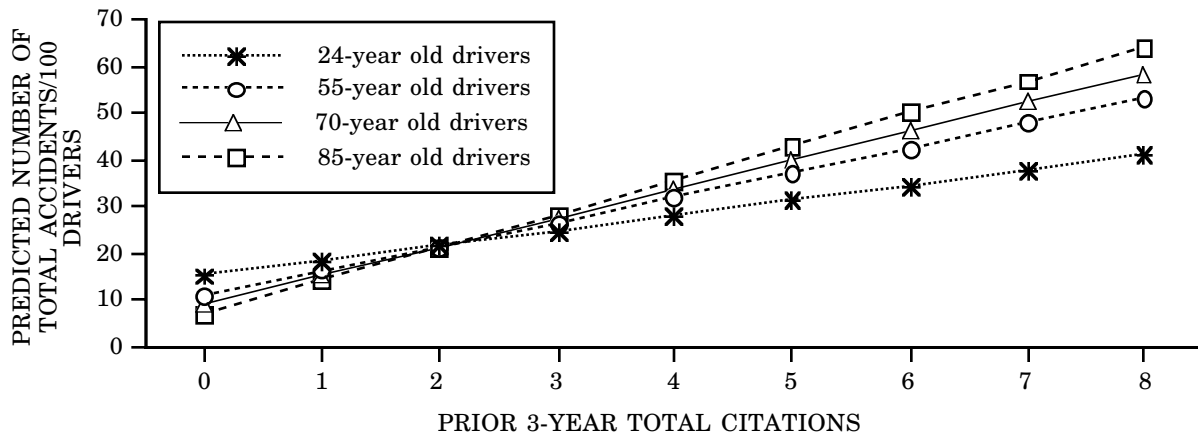


Figure 11. Expected number of total accidents during a 3-year (1989-91) period by age and prior 3-year (1986-88) total citations.

Figure 12 illustrates the expected number of subsequent total accidents by sex and prior 3-year total citations. These data indicate that at lower citation levels, the accident rate for men exceeds the accident rate for women. At higher citation levels, the accident rate for women is approximately equal to, or slightly exceeds, that for men. For example:

- Among drivers with zero prior citations, there is a rate of 14.43 accidents per 100 male drivers and a rate of 10.73 accidents per 100 female drivers, for a relative risk differential of 1.34 times-as-many accidents for male drivers.

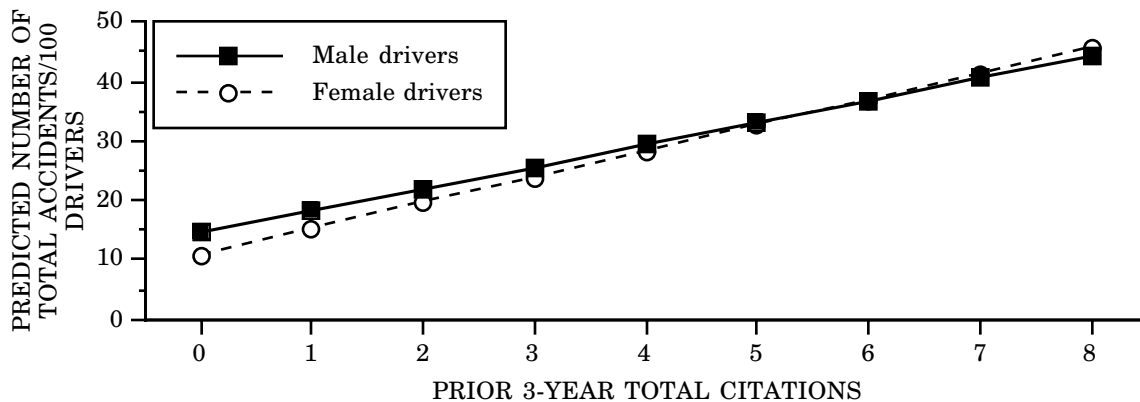


Figure 12. Expected number of total accidents during a 3-year (1989-91) period by sex and prior 3-year (1986-88) total citations.

- Among drivers with eight prior citations, there is a rate of 44.21 accidents per 100 male drivers and a rate of 45.49 accidents per 100 female drivers, producing a relative risk differential of 1.03 times-as-many accidents for female drivers.

Figure 13 shows the expected number of subsequent total accidents by driver license class and prior total citations. This figure indicates that at each prior-citation level, commercial drivers have a higher accident rate than do noncommercial drivers. However, the rate of increase in accident rate over successive prior citation levels is actually higher among noncommercial drivers. For example, Figure 13 indicates that:

- Commercial operators with zero citations have an expected accident rate of 23.39 per 100 drivers. Commercial operators with eight citations have an expected accident rate of 66.95 per 100 drivers. This results in a relative risk differential of 2.86 times-as-many accidents for commercial operators with eight citations relative to commercial operators with zero citations.
- Noncommercial operators with zero citations have an expected accident rate of 12.24 per 100 drivers. Noncommercial operators with eight citations have an accident rate of 43.42 per 100 drivers. This results in a relative risk differential of 3.55 times-as-many accidents for noncommercial operators with eight citations relative to noncommercial operators with zero citations.

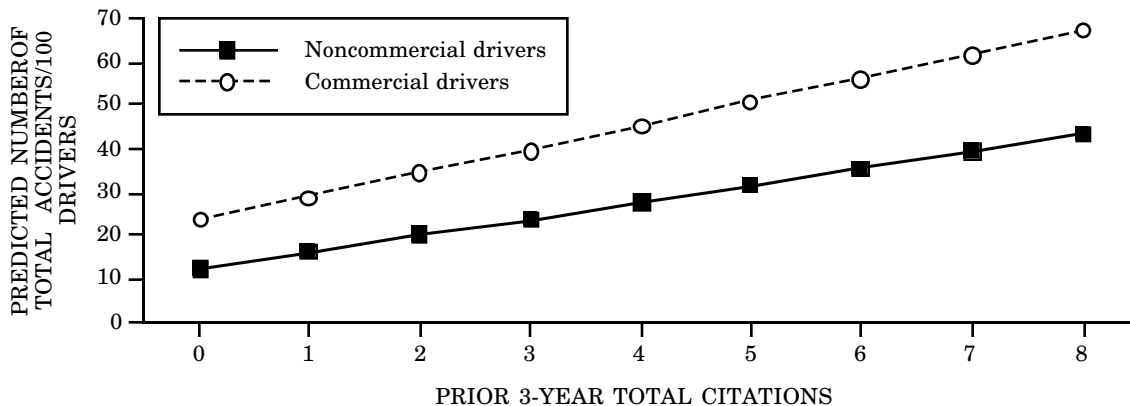


Figure 13. Expected number of total accidents during a 3-year (1989-91) period by license class and prior 3-year (1986-88) total citations.

### Territory Variables

The California Driver Record Study also contains the driver's ZIP Codes, but it was not possible to include an analysis of the role of territorial variables as risk factors in this report. We do know from an earlier study (Peck & Kuan, 1983) that ZIP-Code variables do have some relationship with accident risk. Peck and Kuan found that the inclusion of ZIP-Code variables to multiple regression equations increased their

multiple  $R$  from .193 to .204. The role of ZIP Code and territorial variables will be assessed in a subsequent report.

### Conclusions

- Accident risk is a complex function of many variables, and strategies for predicting individual accident risk must be multidimensional in form.
- Prior total citation frequency was the most significant predictor of accident involvement followed by prior accident involvement frequency. Increased accident involvement was shown to be associated with increased prior citation and accident frequency, possessing a commercial driver license, being young, being male, having a medical condition on record, and having a physician referral for low visual-acuity on record.
- Older drivers exhibit a steeper increase in future accident risk at successive prior incident levels, relative to younger drivers.
- At lower citation levels, male drivers have a higher accident rate than do female drivers. At higher citation levels, the accident rate for female drivers is approximately equal to, or slightly exceeds, that for male drivers.
- At each prior citation level, commercial drivers have a higher accident rate than noncommercial drivers. However, the rate of increase in accident rate is actually higher among noncommercial drivers.
- The relationships are primarily additive and linear. Very little additional predictive accuracy is gained by considering the significant non-linear and non-additive components.

Table 57

Results of Multiple Regression Analysis for the Prediction of Total Accident Involvement Using Nonconcurrent 6-Year Data (1986-88; 1989-91)

Predictor variable (1986-88)	Simple correlation coefficient	Multiple <i>R</i>	Unstandardized regression coefficient at final step	Standardized regression coefficient at final step	<i>F</i> at final step	Significance ( <i>p</i> ) level	Equation summary
Total citations	.120	.120	0.029	0.083	929.72	.000	$R^2 = .025$
Total accidents	.090	.137	0.059	0.063	586.85	.000	Y-intercept = 0.158
Class of license	.064	.147	0.118	0.047	338.06	.000	Standard error for criterion estimate = 0.409
Age	-.073	.152	-0.001	-0.042	255.97	.000	<i>F</i> for the final equation = 486.16
Sex	.063	.155	0.028	0.034	173.24	.000	$p = .000$
Prior out of state license	-.027	.156	-0.042	-0.019	58.28	.000	
Medical (physical/mental) condition on record	.025	.157	0.060	0.017	44.31	.000	
DL-62 physical vision referral on record	.001	.158	0.038	0.007	8.19	.000	

Note. Predictors listed in sequence of stepwise entry have  $p < .10$ ;  $N = 152,931$ .

Table 58

Odds-Ratio for Prediction of Total Accident Involvement Based  
on 6-year Nonconcurrent Data (1986-88; 1989-91)

Predictor variable	Odds-ratio
Total citations	
0 vs. 1	1.15
0 vs. 2	1.32
0 vs. 3	1.52
0 vs. 4	1.75
Total accidents	
0 vs. 1	1.33
0 vs. 2	1.77
0 vs. 3	2.35
Class of license (commercial vs. noncommercial)	1.68
Age	0.99
Sex (male vs. female)	1.24
Prior out-of-state license (yes vs. no)	0.68
Physical and mental condition on record (yes vs. no)	1.31

Note. Predictors listed are significant at  $p < .001$ . Chi-square for entire model (all predictors) = 1,111.48 ( $p < .001$ );  
N = 152,931.

Table 59

Results of Multiple Regression Analysis for the Prediction of Total Accident Involvement Using Nonconcurrent 6-Year Data (1986-88; 1989-91)

Predictor variable (1989-91)	Simple correlation coefficient	Unstandardized regression coefficient at final step	Standardized regression coefficient at final step	F at final step	Significance (p) level	Equation summary
A. Total citations	.120	0.351	0.102	688.59	.000	<u>Main effects model</u>
B. Class of license	.064	0.124	0.049	128.33	.000	$R^2 = .024$
C. Total accidents	.090	0.057	0.060	458.22	.000	$F = 754.83$
D. Sex	.063	0.027	0.033	152.15	.000	$p = .000$
E. Age	-.073	-9.569 E-04	-0.035	165.33	.000	<u>Main effects and interaction model</u>
A x B	.039	0.012	0.008	8.84	.003	$R^2 = .025$
A x C	.057	-1.605 E-04	-3.479 E-04	0.01	.910	$F = 264.57$
A x D	.048	-0.005	-0.008	5.84	.016	$p = .000$
A x E	-.048	4.057 E-04	0.018	26.98	.000	Y-intercept = 0.154
B x C	.044	0.066	0.017	38.06	.000	Standard error of estimation for main effects and all 2-way interactions = 0.409
B x D	.040	-0.053	-0.010	5.97	.015	
B x E	-.014	6.355 E-04	0.003	1.10	.294	<u>Change from adding interactions</u>
C x D	.039	0.033	0.017	40.51	.000	$R^2 = .001$
C x E	-.015	5.648 E-04	0.009	10.90	.001	$F = 19.00$
D x E	.001	4.290 E-04	0.008	8.79	.003	$p = .000$

Note. Predictors were entered hierarchically, with all main effects entered first and interactions entered last.  $N = 152,931$ .

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## APPENDIX

### Description of Variables Used in Data Analyses

#### Total Accidents

Accident data presented in this report represent reported accidents only. California Vehicle Code (CVC) Section 16000 requires the driver of every motor vehicle involved in an accident resulting in damage to the property of either party in excess of \$500, or in bodily injury or death of any person, to submit a written report to the Department of Motor Vehicles. Failure to file a report under the above conditions will result in suspension of the driving privilege. Accidents involving injury or fatality must also be reported to the DMV by the California Highway Patrol.

It should be noted that throughout this report, use of the term "accidents" actually means "accident involvements." More than one driver can be (and indeed usually is) involved in any given accident. If a driver in the 1% random sample collided with another driver from within the same sample, this would be counted as two involvements—one for each driver—although both involvements would represent the same accident. If a driver in this sample collided with a driver outside of the sample, the accident would count as one involvement.

#### Fatal/Injury Accidents

These are accidents resulting in death or injury. A fatal accident results in the death of one or more persons within 30 days of the accident. An injury accident results in a severe wound or other visible injury to, or complaint of pain from, one or more persons.

#### Responsible Accidents

These are accidents in which the driver is indicated by the investigating officer to have been at least partly responsible.

#### Total Citations

The citation count includes convictions, failures to appear in court (FTAs), and traffic violator school (TVS) dismissals in the defined time period (based on violation date). A citation that is dismissed conditional upon the offender's completion of TVS is not an actual conviction. Each citation incident is counted as only one conviction, one FTA, or one TVS dismissal, even if there are multiple violations (e.g., when a driver is cited for speeding and failing to stop for a red light on one "ticket"). Total citations are also presented after excluding TVS dismissals.

#### Countable Citations

These are countable convictions and TVS dismissals. Countable citations are usually for safety-related violations (e.g., speeding, right-of-way, DUI, and hit-and-run).

### Moving Citations

These are convictions and TVS dismissals for safety-related violations, excluding the more serious violations (e.g., DUI and hit-and-run).

### Major Citations

These are convictions for serious violations (e.g., DUI and hit-and-run).

### Negligent-Operator Points

In determining neg-op points in California, one point is entered on the driving record for each moving-violation conviction (e.g., speeding, unsafe turns), except those involving "major" offenses such as driving under the influence of alcohol/drugs, reckless driving, and hit-and-run. The latter convictions count as two points each. If a violation occurs while a licensed commercial operator is driving a commercial vehicle or transporting hazardous material, then the normal point count for the conviction is multiplied by 1.5 (i.e., a one-point conviction becomes 1.5 points, and a two-point conviction becomes three points). An accident for which the driver is deemed at least partly responsible counts one point. In order to maintain consistency with prior Driver Record Study reports, all accidents were assigned one point. As defined by CVC Section 12810.5, drivers with a class 3/C (personal auto or pickup truck) driver license are defined as neg-ops when their driver records contain four or more points in 1 year, six or more points in 2 years, or eight or more points in 3 years.

### TVS Citation Dismissals

These are traffic citations that were dismissed contingent upon completion of a state-certified TVS program as defined in California Vehicle Code Section 42005.

### Class of License

This is the primary class of driver license as recorded on an individual's driving record. In California, the classes of driver licenses are:

A – May drive any vehicle or combination of vehicles (except motorcycles).

B – May drive large, multi-axle vehicles and autos.

C – May drive small buses, small trucks, and autos (regular driver license).

M1 – May drive motorcycles only.

M2 – May drive small motorcycles only.

### State Last Licensed

This is an abbreviation on the driving record indicating that an individual had a driver license in another state.

### Physical or Mental Code

This indicates the presence or absence of a medical condition.

### DL-62 Code

This is the presence or absence of a physician referral (DL-62) for low visual-acuity.